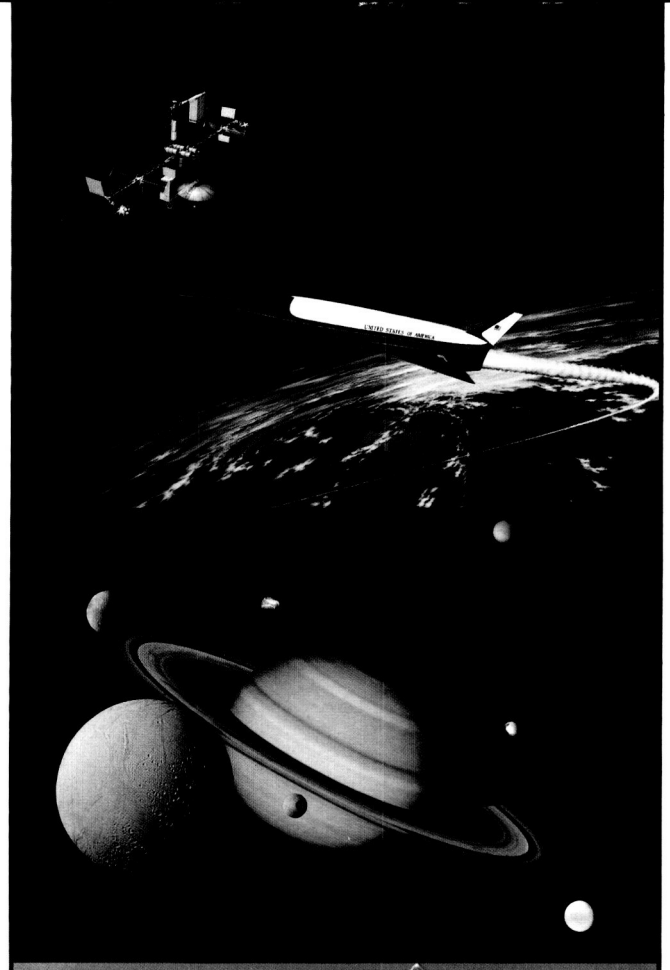
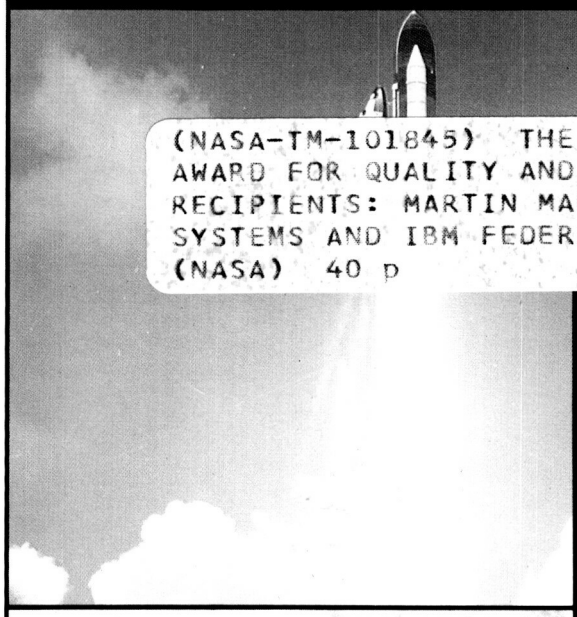
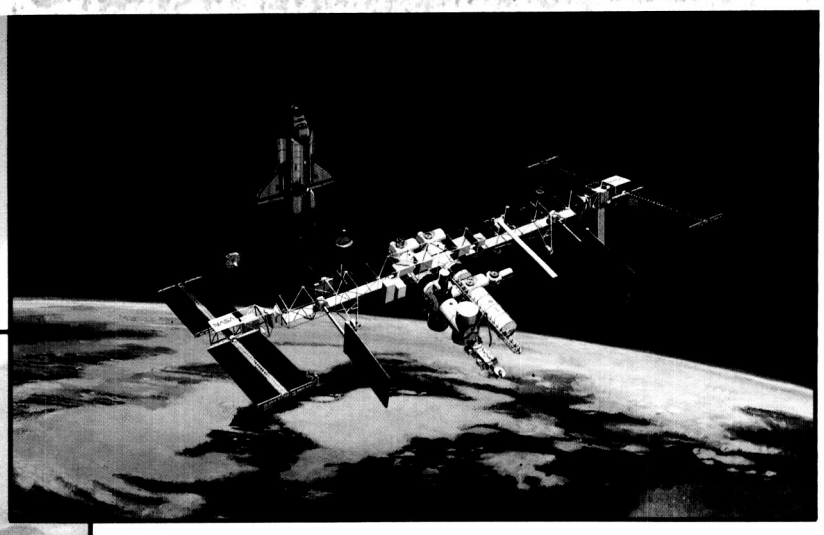


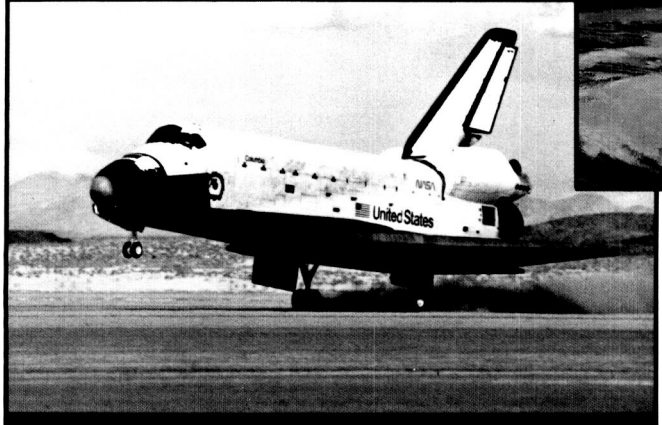
HIGHLIGHTS

1986

NASA Excellence Award for Quality and Productivity







NASA
National Aeronautics and Space Administration

December 1987

1986 NASA Excellence Award for Quality and Productivity Recipients

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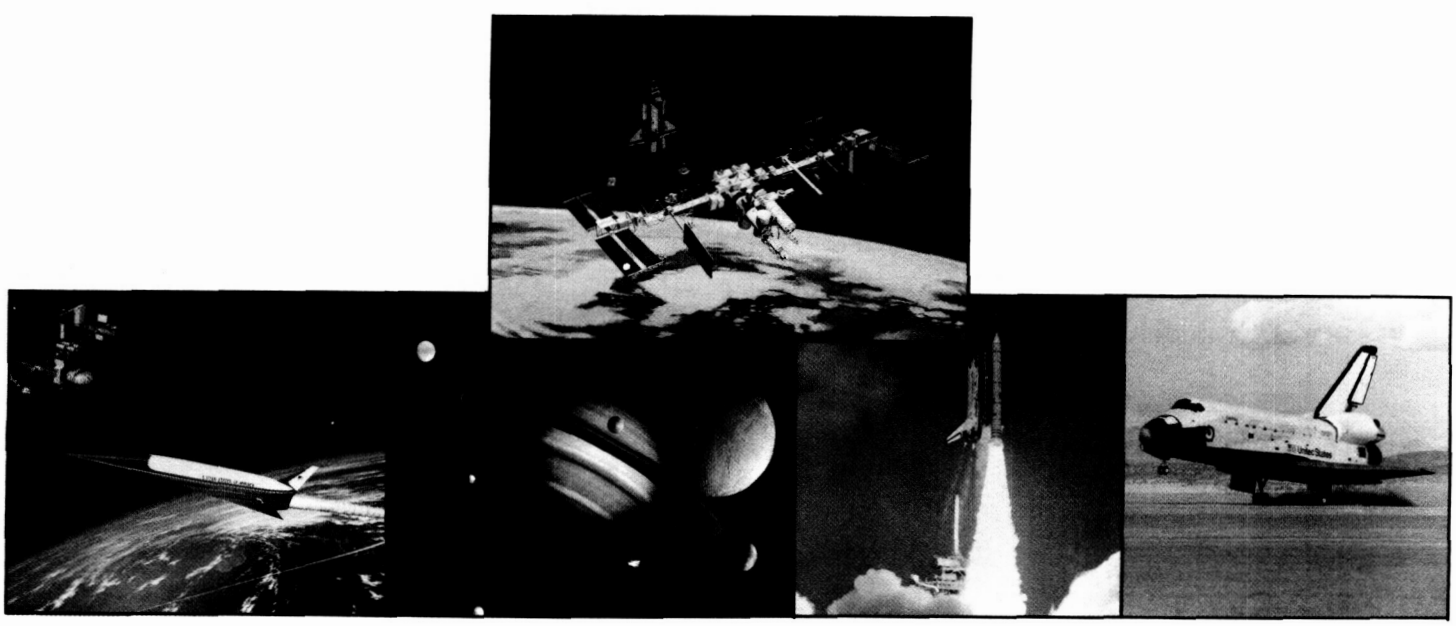
Martin Marietta Manned Space Systems
IBM Federal Systems Division

Conducted by the
National Aeronautics and Space Administration
Office of Safety, Reliability,
Maintainability and Quality Assurance
with the assistance of the
American Society for Quality Control

December 1987



Contents

Preface

The NASA Excellence Award for Quality and Productivity was created and designed to recognize those companies which have achieved and demonstrated accomplishments in quality and productivity at the highest level. We believe that the NASA Excellence Award can provide the motivational environment and the incentive for our contractors to continually seek quality improvements. It is clear from the past two years that outstanding companies have demonstrated commitment by the highest level of management and by the entire work force for quality and productivity. The aura of success is certainly prevalent at these outstanding companies and could easily be detected by our on-site teams.

We believe this award process, in the beginning of its third year, is showing the benefits to be derived from it. It is starting to develop a learning environment for those organizations seeking to improve the quality and productivity of their products and services.

This "Highlights" booklet spells success in the form of the excellence in the performance and quality of work accomplished by Martin Marietta and IBM—this year's award recipients. The booklet details the efforts on their part in achieving outstanding performance and excellence in Quality Enhancement and Productivity Improvement. Also, it serves as a learning tool for aerospace companies, American industry and government.

Harry Quong, Director
Reliability, Maintainability and Quality
Assurance Division
Office of Safety, Reliability,
Maintainability and Quality Assurance

Foreword

Quality improvement is a precursor to excellence. To continue to succeed, we must continue to improve our quality. We must consistently do our best. Then the vision, skill, and technology that have been our trademark will continue to drive us toward even greater achievements. To further these aims, NASA annually presents the NASA Excellence Award for Quality and Productivity to those NASA aerospace companies—both large and small—whose products exemplify the highest standards of performance. The award recognizes organizations that continually seek to improve and demonstrate the quality of their products and services.

I wish to thank all the contractors that applied for the Excellence Award and my special congratulations to Martin Marietta and IBM—the award recipients for 1986. With the Excellence Award criteria clarified in more detail in 1987, we look forward to greater NASA contractors participation in this important program.

George A. Rodney
Associate Administrator for Safety,
Reliability, Maintainability
and Quality Assurance

Martin Marietta Manned Space Systems

Developing and improving productivity while maintaining high quality is standard business practice at Martin Marietta. We simply have to be — and I believe there is significant evidence that we are — committed to working productively every day. We have an ethical obligation and a social responsibility to produce products of the highest quality at prices our customers can afford, and our commitment is an integral part of discharging that responsibility.

We have worked diligently to develop a "mission success" culture at every level of our organization. The Space Shuttle external tank project is an excellent example that our efforts are producing results.

Our record of building and delivering tanks of the highest quality, on schedule, while at the same time increasing production rate and reducing both costs and nonconformities, speaks for itself.

Thomas G. Pownall
Chairman and Chief Executive Officer
Martin Marietta Corporation

Martin Marietta Corporation established the management commitment review, and support for achieving high product quality and productivity more than a decade ago. At Manned Space Systems we established our mission and set strategy for quality enhancement and productivity improvement within all levels of the organization. As a result, we have developed a positive long-term effort which is permanently integrated into our philosophy and strategic planning. This effort is on a level with the other major functions of the company. It is a total process that supports the company for better operations through the employment of all its resources.

In our terms, three principles are central to understanding the approach we take to productivity improvement and quality enhancement.

- Ensure "mission success" with strong emphasis on product quality in process and after delivery, including our support service operations.
- Assure that our manufacturing processes are consistent with safety, environmental standards, and energy conservation.
- Continue to improve people management and employee quality of work life.

These principles serve as the general controlling standards and guidelines for our productivity program.

Our efforts stress quality, productivity improvement, and mission success on a continuing basis, beginning with the above foundation and applying the following techniques:

- Involve each employee in the process.
- Overcome each potential impediment to improvement.
- Establish measurable goals.
- Make each improvement correspond with real savings.
- Ensure that the customer (NASA) is part of the productivity and quality improvement initiative.

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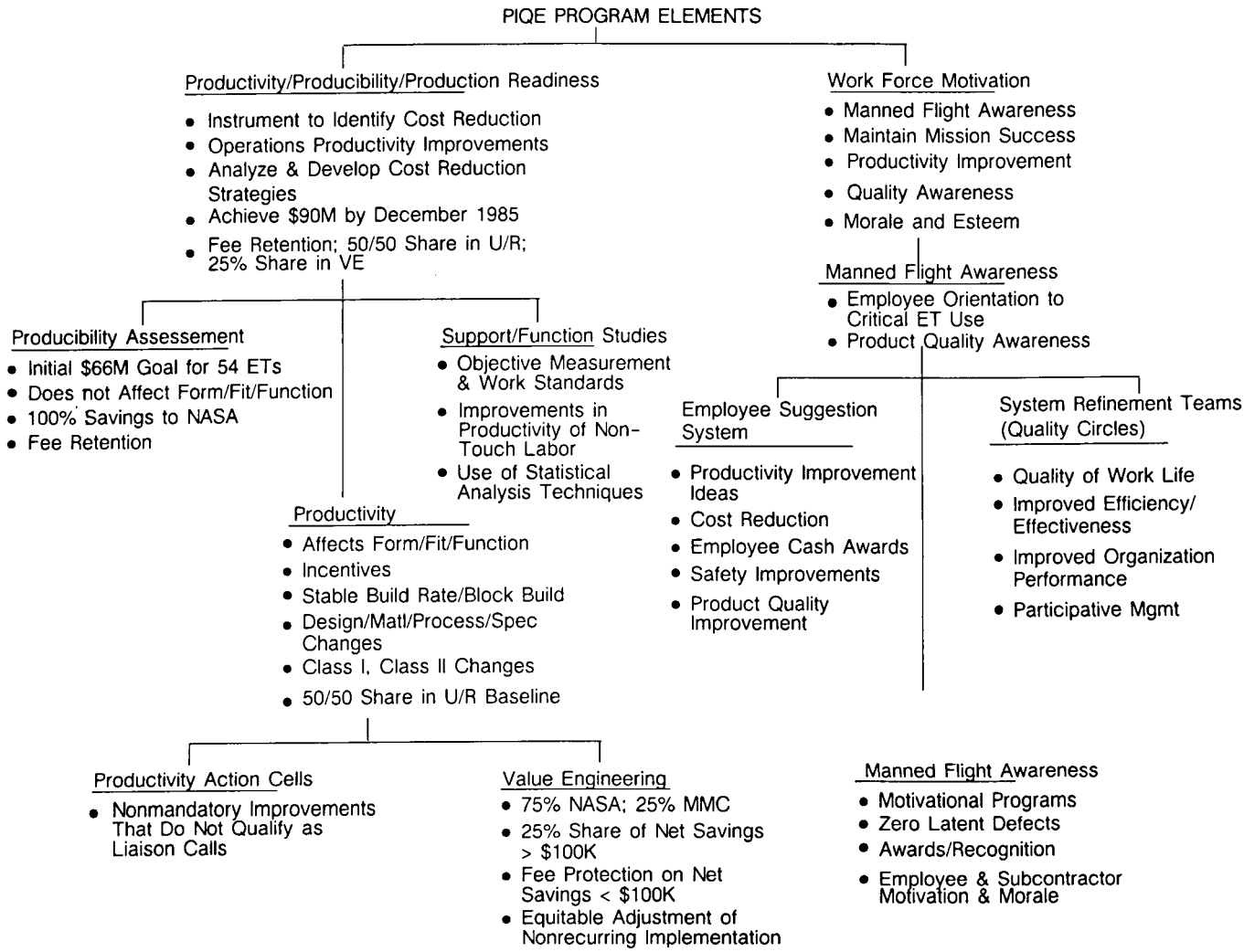


Figure 1. Productivity Improvement Quality Enhancement Program Elements

At Martin Marietta Manned Space Systems we have made a total commitment to quality and productivity improvement. The responsibilities for developing and implementing this commitment have been assigned and permanently integrated into our management philosophy and strategic planning. Figure 1 illustrates our commitment organized by element, goals, criteria for each, and the relationship of the elements to each other. To make the effort real and to achieve the objectives within schedule, each of our departments was assigned goals as a percentage of improvement committed to our customer. A productivity integrator was put in charge at the top management level to coordinate the commitment and to develop long-range plans for continued improvement. Quality enhancement and productivity improvement candidates are submitted to our Productivity Committee for assessment, evaluation, and recommendation to assure that each candidate is coordinated throughout Manned Space Systems.

The ongoing integration of initiatives into the functional departments and manufacturing operations continues to generate substantial benefits to the company and customer. We have exceeded initial productivity goals a year ahead of plan and returned to NASA a substantial return on investment over the present contracted project.

The effectiveness of our performance on the External Tank (ET) program may be gauged by the following results:

- Manufacturing performance for the External Tank has improved by 71% from the second quarter 1983 through the third quarter 1986.
- Planning errors, as represented in the number of errors per page found during quality review cycle of stand-alone Manufacturing Process Plans (MPP), have been reduced by approximately 77% from the first quarter 1983 through the third quarter 1986.
- Engineering errors, as indicated by the number of requests for correction (liaison calls) initiated, have decreased by 38% during the period 1983 to 1986.
- A reduction of 81% in major hardware nonconformances on "lightweight" model ET's in work as measured by Martin Anomaly Reporting System (MARS) documents, over "heavyweight" model.

- A 47% reduction in the number of discrepancies per part for major supplier hardware delivered from the second quarter 1983 to third quarter 1986.
- A 98% reduction in latent defects (defects not discovered until after the ET is delivered to NASA) has been achieved. This is a significant measure of the success of our Productivity Improvement and Quality Enhancement (PIQE) program. Major reductions in nonconformances have exceeded the customer's goal of less than six latent defects for ten successive delivered External Tanks. None of the latent defects has caused launch delays or required a significant launch site effort to resolve.

We achieved these results while reducing quality labor costs 29% from 1983 to 1985. The list of additional achievements in quality and productivity is long and growing. Of course, no progress could be made without our committed proactive management dedicated to continuing these efforts.

Commitment

The formal implementation of our total PIQE effort was initiated by Thomas G. Pownall, chairman and chief executive officer, in his direction to all executive management, "Identify to me by January 15, the measurement units for the most critical/meaningful productivity criteria for the various elements under your control using 1978 as the base year . . . ."

Effective Communication

Open communication throughout staff and line functions is regularly reinforced. Our executive management holds general meetings for all shifts to discuss major challenges, and to illustrate the crucial aspects of our quality and productivity improvement process as they affect our system.

Effective communication is essential to the success of any business, a fact we at Martin Marietta know well and practice daily. Our 1984 employee survey demonstrated that two-way communication is an integral component of operations at Manned Space Systems. The results of the employee survey are shown as follows:

- Commitment to mission success 99% favorable
- Commitment to customer 98% favorable
- High quality product and service 97% favorable

Continuing follow-up surveys will ensure that systemic issues relating to productivity and quality of work life are identified and problems resolved. The next survey is scheduled for early 1988.

Innovation

We recognize that to ensure continued success we must be innovative in our approach and be able to provide rewards to our employees. Furthermore, our understanding of both the technical and organizational aspects of innovation is essential to the critical interrelated objectives we pursue at Manned Space Systems. These include:

- A strategy that, from initial design through delivery, considers quality as vital as technical requirements and schedule, and cost, that provides our customers cost-effective, high quality products and services.
- The conduct of our daily business according to the highest ethical standards.
- The achievement of superior performance at every level of the organization, with emphasis on quality, safety, and reliability.
- The participation of the total work force in submitting new ideas, improved processes, and technologies.

Through our Employee Suggestion System (ESS), we continually address improvements to quality, productivity, safety, schedule and cost. The ESS provides employees a method of presenting constructive ideas to management and when implemented, provides recognition and awards for their contributions.

To date the Suggestion System has resulted in 2,120 implemented improvements to the product, processes, and External Tank system, and 1,096 improvements to personnel and product safety. Cumulative savings total $4,937,457 with a current return of $10 in savings for each $1 expended on awards and administration of the system.

Our participation rate of 67 suggestions per 100 employees during 1985 is more than two and one-half times the aerospace industry average of 26, according to the National Association of Suggestion Systems' (NASS) 1985 statistical report. Our average suggestion turnaround time of 56 days is less than a third the industry average of 183 days according to NASS statistics.

The Zero Latent Defects Program was implemented in October 1980 for employees to accept, as a personal responsibility, the goal of detecting and eliminating all latent defects. This program continues to be effective and supported by the work force. The program has helped us realize a 98% reduction in latent defects on delivered tanks (Figure 2). In 1985 employees detected 242 *potential* latent defects which prevented them from reaching a *delivered* latent defect status. This year, 225 potential latent defects have been identified and corrected.

As part of the Zero Latent Defects Program, a total of 2,034 latent defects have been detected and

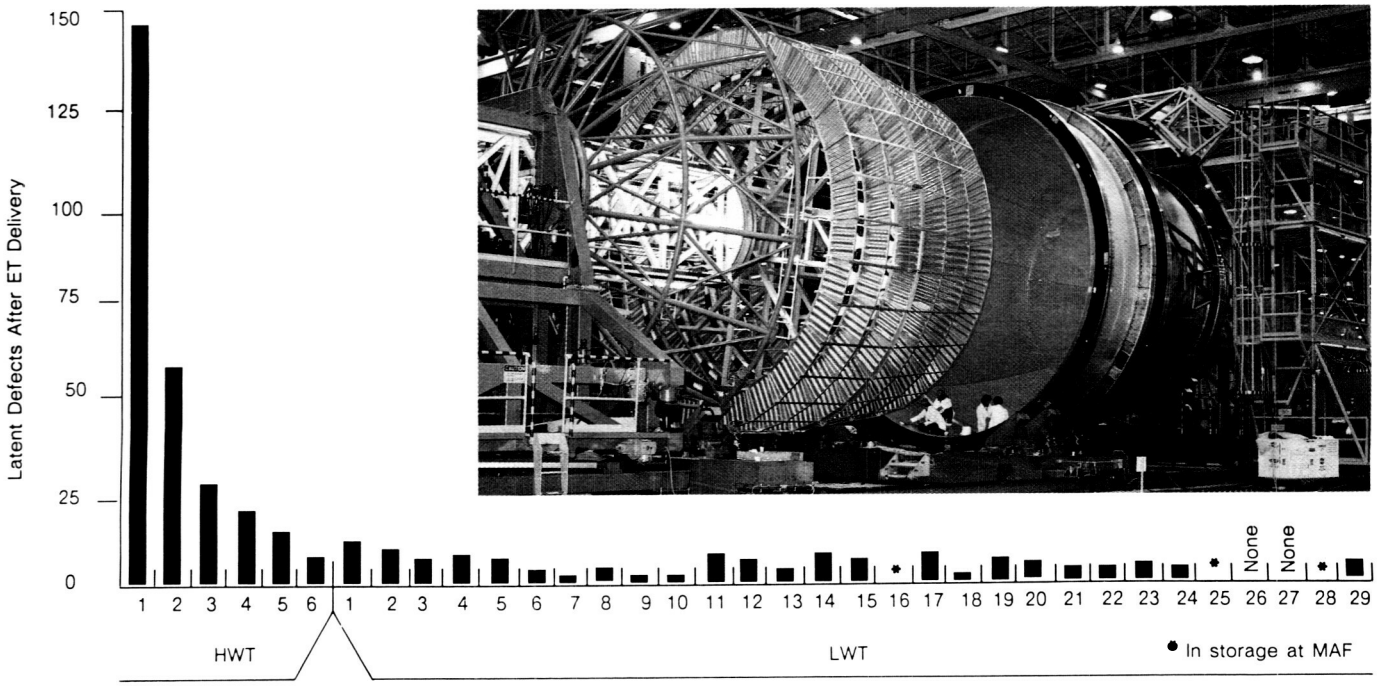
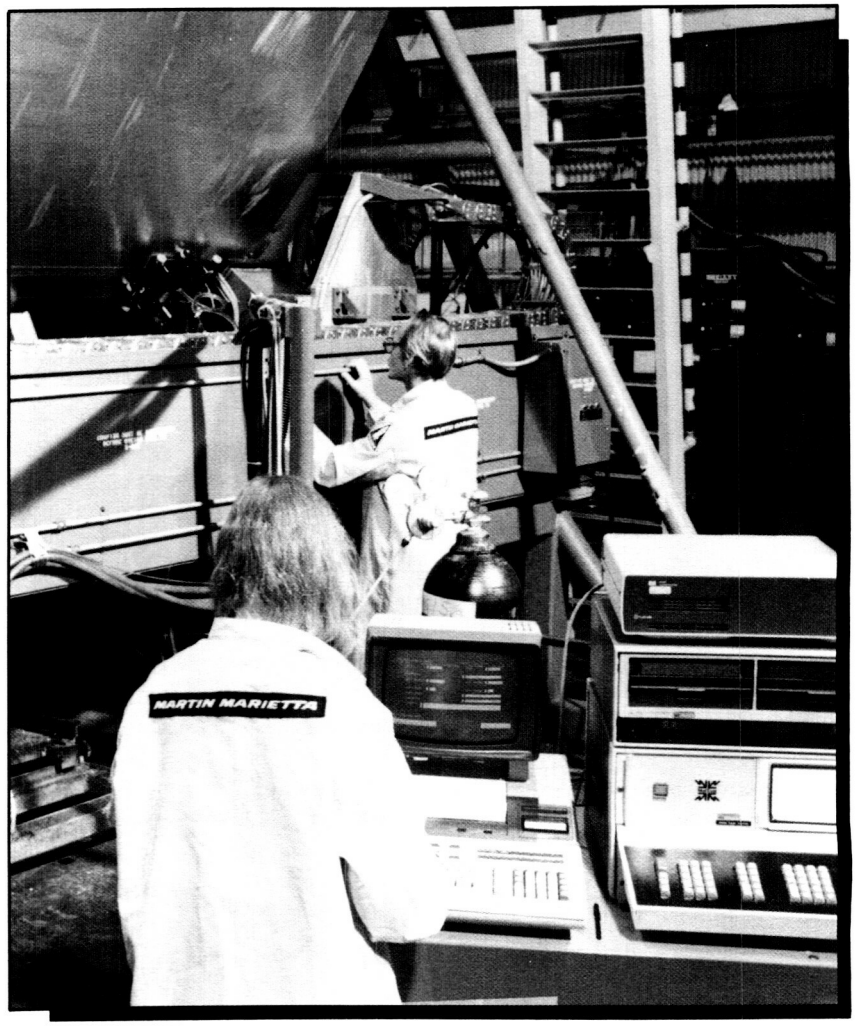


Figure 2. Latent Defects per ET Delivery



In motion x-ray of variable polarity plasma arc weld for the external tank of the space shuttle helps assure the quality of every inch of weld in the 154-foot long tank.

eliminated. This program has created a positive overall defect consciousness among employees and has provided early detection and timely correction of latent defects. Resulting benefits of this program include mission, safety, schedule, and cost reduction.

Over the past five years, our employees submitted 89 new technology disclosures/new idea reports that have resulted in cash awards from both Martin Marietta and customer sources. In addition, seven patent applications were made, including one for a robotic intelligence safety system.

Dedication, Pride, Teamwork

The successes of our productivity improvement and quality enhancement programs have been achieved by the establishment of employee participation, understandable measures, and achievable goals. The impact of pride, dedication and team effort on this is reflected by our Systems Refinement Team (SRT) or quality circle process. The SRT concept embodies a variety of employee structures, including work group, task force, integrated, and management teams. Team members are provided with the concepts and skills of systems refinement, which include training in work-study methods, problem solving, project management, leadership, and team building. In addition, Systems Refinement is a flexible process that fits the design of our organization, but most important it involves management and employees in the improvement process.

Systems Refinement Teams work by integrating people, technology, and systems both vertically and horizontally within our organization. Vertical integration is accomplished through top-down participation in advisory and support committees, leader councils, management teams, and work group teams. Horizontal integration is facilitated by participation in task force and integrated teams.

From 1983 through 1985, we further improved the process by:

- progressively removing the dependency factors inherent with the quality circle process; and
- changing the focus from problem solving to anticipation, and refinement of the work.

Institutionalization of the Systems Refinement concept continued to progress significantly during 1985-1986. We experienced improvements in the quality of team operation, team projects, team technical support, and team management support at every level. To date, our SRTs have implemented a total of 480 projects, including 204 cost/productivity projects, 150 quality improvement projects, and 128 projects related to safety, training, communication, and quality of work life. Some examples of SRT projects are shown below:

Team	Improvement	Benefit
Change Summary Group	Change Summary Amendment	$271,000 first year savings
Thermal Protection System Molding	Alternative test procedures	$12,240/ET savings
Mech Final Assembly	Certification/recertification procedures	$4,400/ET savings
TPS Final Assembly	Reduction in test specimens	$3,520/ET savings
TPS Final Assembly	TPS damage prevention during the final assembly closeout activities	Improved quality
Weld Subassembly	Portable racks for C-Ring storage and transfer	Improved safety
Data Base Loaders	CAD release procedures	Schedule improvement

Further evidence of the effectiveness of SRTs is shown by comparing a five-year average of hourly SRT members to hourly employees not yet participating.

37.0% lower rate of unpaid lost time among SRT members

26.1% lower rate of grievances among SRT members

23.8% lower rate of safety accidents among SRT members

32.5% lower rate of safety incidents among SRT members

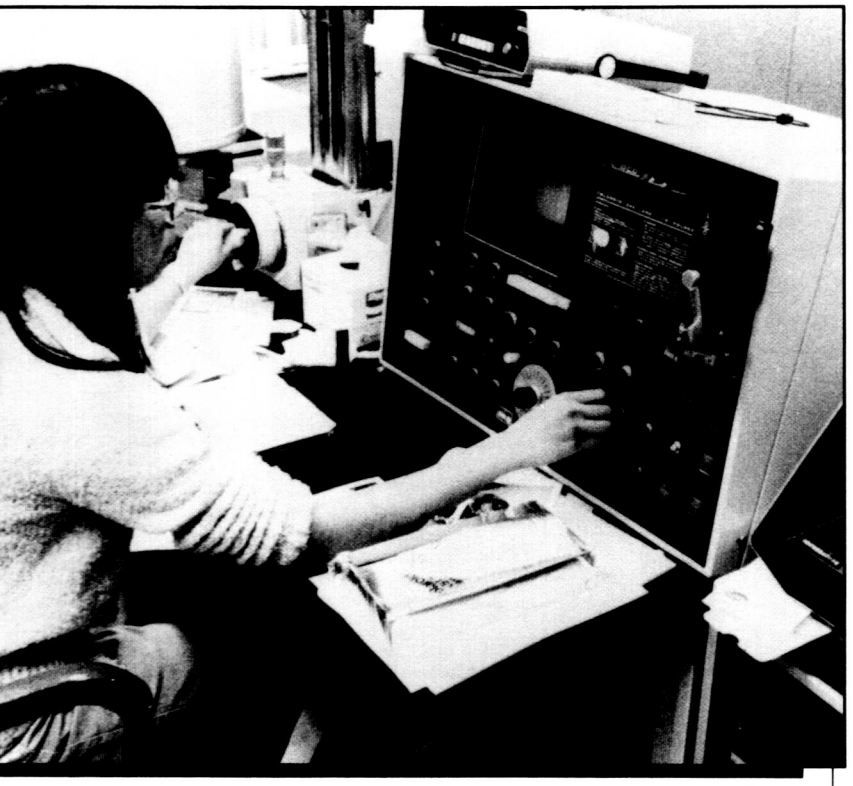
52.1% lower rate of attitude-related attrition among SRT members

23.8% lower rate of employee attributable hardware nonconformances (MARS) among SRT members

Our SRT program has been recognized by the International Association of Quality Circles (IAQC) as the best in the country. This was demonstrated in 1985 when Martin Marietta Manned Space Systems became the sole recipient of the IAQC "Award of Excellence."

Talent and Progress

Martin Marietta's management believes that we have the responsibility to provide the proper balance of administrative restraints while supporting our achievers' drive and zeal if we are to be successful. Our organizational structure combines systems, rewards, and people in such a way that "champions" flourish. Our system capitalizes *on* and *rewards* the efforts of individuals and groups throughout the organization.



Technician Laura Rowland works in Martin Marietta's Advanced Quality Engineering Laboratory.

An example of our continued effort to control bureaucracy was the introduction of the Change Summary Amendment (CSA) — management's documentation control procedure — by an integrated team of "champions." First introduced in 1985, the CSA allowed for the processing of some changes that previously would have required a supplement document or a complete issue. The first-year savings to the customer was $271,000, and during the following year the savings exceeded $500,000.

Our "champions" receive awards in different ways, ranging from monetary awards to a "well done" from their peers. In 1985 more than 43% of our work force was recognized for their individual performance. These awards include, but are not limited to, peer recognition, six-month sustained high achievement, "Silver Snoopy", Employee of the Month, and Employee of the Year. By first quarter 1986, 24 employees were honored by the company for their outstanding achievement in improving productivity and significantly enhancing the quality of delivered hardware. At the close of 1985, 108 employees were recognized and received the Director's Spot Award totaling more than $28,000.

Another facet of our recognition is the company's supplemental incentive award that specifically recognizes individuals who exceed company performance goals and objectives. In 1984, 23 employees received a total of $32,000, 13 employees received $16,500 in 1985, while 10 received $21,515 through the third quarter of 1986.

New Technology

At Martin Marietta Manned Space Systems, our entire engineering data base is being converted to computer-aided, three-dimensional models — one of the largest such CAD/CAM undertakings known. Ongoing implementation for Communication Interface Equipment will eventually integrate the entire facility.

Another continuing program of office automation is our ongoing and aggressive support of factory automation (which will include and upgrade all manufacturing plans), bar code applications, and graphic/text integration.

Our factory automation program has provided increased visibility of critical performance measures and decreased reporting turnaround time. This has significantly improved availability of data and correspondence requests. We significantly improved software applications with the addition of major computer systems in 1984. Our MOTION system provides real-time data on work-in-progress throughout the factory as well as labor accounting, with labor performance based on work standard. These data are provided through floor transitions accomplished by the individual employee.

Our production control data reporting computer system provides personnel a running status on work in process and can provide rapid response information on variances. We also developed a functional cost management computer system which automates the forecasting, collection, and reporting of direct and support labor. As a result, we have reduced staff while improving data quality required for factory cost control.

Our tool status accounting system provides current information on 15,000 tools, including the relation of the tool configuration to the External Tank. This system tracks the production of new tools as well as the maintenance, certification, and quality acceptance of existing tools. With this inclusion, data feedback is timely and provides an improved status capability.

Our factory operations planning has resulted in development of sophisticated scheduling systems which provide integrated plans emanating from the project level to individual work station and component schedules. Status is analyzed and reported at each level for optimal management evaluation and avoidance of potential problems. Schedule applications are primarily mechanized, with bridging programs between systems which facilitate real-time interchange of information and direction. This ongoing approach has enabled a 90% acceleration in incorporation of schedule revisions by users and a 30% reduction in planning personnel since 1983.

Our Material Operations has developed a meaningful Performance Measurement System (PMS) program that indicates Material's performance purchasing hardware to support the manufacturing effort. Performance Measurement System measures

planned receipts of hardware into inventory stores versus actual receipt into inventory stores. This program calculates earned value, cost and schedule variances, expenditure forecasts and variances, and can compute equivalent vehicle hardware receipts.

Martin Marietta is continually searching for new approaches and products with the realization that procuring the latest technology is not enough. We have increased emphasis on technology transfer to ensure continued quality and productivity improvement. Our prime motivation is to fully utilize all of the resources within our organization before seeking expertise from outside resources.

One innovative approach we have taken is to identify specific areas that require technology transfer in order to bring the manufacturing processes into usable state-of-the-art technologies. Our approach provides the mechanism for rapid and successful transfer by bringing together three key partners — the technology resource, our production organization, and the catalyst for directly translating technology into practical production processes — our Advanced Manufacturing Technology (AMT) department. The AMT organization has effectively "bridged the gap" from the research laboratory to production.

One example is the development of a unique cost saving molding process for the ET Thermal Protection System. This process was transferred from the research laboratory to production in less than one year. This innovation eliminated expensive machining, reduced the manufacturing process time, and significantly reduced the amount of abalator material for each component.

A more recent development is to spray foam on the Intertank with one continuous process using two angled spray guns. This new development eliminated a two-foam process and thereby increased reliability. The following listing gives other examples of transferred productivity improvement technologies and associated ET savings.

Productivity Improvement Through Technology Transfer Productivity

Productivity Improvement	Technology Source	Benefits	Savings/ET
Variable Polarity Plasma Arc Welding (VPPA)	MSFC	Reduced weld joint preparation and defects	$85,000
HI Temp Foam	MSFC & NCFI	Eliminated Aft Dome SLA with application foam	$47,000
Ti Investment	MSFC	Reduced machining and repeatable casting dimension	$42,295
Screen Mold (SLA)	MIT	Automated flat parts	$33,000
Gas Injection (SLA)	MIT	Less scrap	$31,500
Pour Ramps (SOFI)	MSFC	Eliminated costly machining in final assembly	$ 8,000
Reaction Injection	MSFC	Critical application in cells G and H	$ 6,550
Robotic Spray	MSFC	Unmanned spray SLA components and MA-255; eliminates safety concern	$ 1,500
Two-Gun Intertank Spray	MSFC	Improved reliability and reduced Orbiter "tile" repair	*
Intertank Rivet Fixture	Gemcor	Automated preparation, installation, and inspection of rivets for the Intertank	*
Weld Tool Development	MSFC	Provides real-time weld profile information that can reduce/eliminate some inspection process	*

MSFC—Productivity Laboratories of the George C. Marshall Space Flight Center
NCFI—North Carolina Foam Institute
MIT—Massachusetts Institute of Technology
* Savings/ET are under evaluation.

With implementation of the joint NASA/Martin Marietta-developed variable polarity plasma arc (VPPA) welding process on the LH2 barrel number 1 and LO2 barrel fixture, T-Ring, Forward and Aft Ogive trim and weld fixtures, and four Dome fixtures, we achieved a 90% reduction in weld defects as compared to the previous Tungsten Inert Gas (TIG) welding process. The VPPA process has also been improved with a new welding torch developed by NASA-MSFC, which eliminates internal water coolant leaks and provides reduced setup time for the welder. In addition to fewer defects, savings are derived from the self-cleaning aspect of VPPA process, which eliminates the hand-cleaning operations required with TIG welded joints.

The automated rivet fixture, which has been implemented to assemble the Intertank half sections and frames, inspects and verifies hole location diameters and rivet installations.

Education and Training

Our in-house training programs at Manned Space Systems build task proficiency in addition to providing personal development and growth. A planned and scheduled training and certification program provides expertise in the area of safety, skills/processes, tooling and facilities, and problem-solving. In addition, our strategy includes the following:

- Executive management support
- Credible and knowledgeable instructors
- Two-way communication between instructor and attendees
- "Tailor-made" programs which fit the specific training requirements
- Ability to transfer classroom training to work stations
- Constant review and feedback between participants and executive management
- Knowledge of attendees

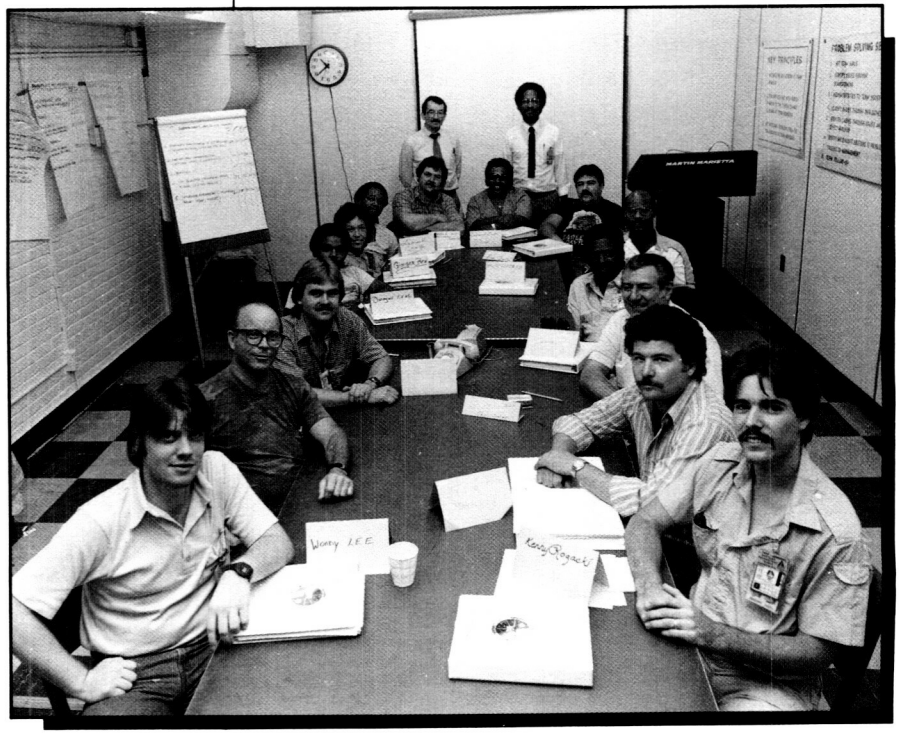
Stated previously in this document, but worth stating again, is the significant fact that nearly 82% of the total work force has attended developmental programs totaling more than 108,000 contract hours.

All of our employees are also encouraged to upgrade their formal education through our policy of reimbursing 100% of tuition costs, books, fees, and other related course materials.

The Training and Certification program, established to develop production skills, provided an overall training curriculum base of 3,800 hours. The objectives of our program are to provide knowledge in the areas of project safety, skills/processes, tooling, and facilities. Our personnel also obtain fundamental job knowledge as well as preparation for certification.

Certification is required to ensure product integrity through use of qualified personnel for performance of all activities which contribute to program success. Special emphasis is placed on computer training to ensure maximum use of our computer network and software programs to increase support and touch labor productivity.

In 1984, classes were developed with a curriculum base of 613 hours of hands-on-hardware training. Productivity gains were immediately realized and training was expanded to a more advanced curriculum base of 980 hours capable of sustaining improved effectiveness and efficiency of our computer user community. In 1985, 883 training sessions were conducted with a total of 19,400 student classroom hours completed.



A Martin Marietta Integrated System Refinement Team in action.

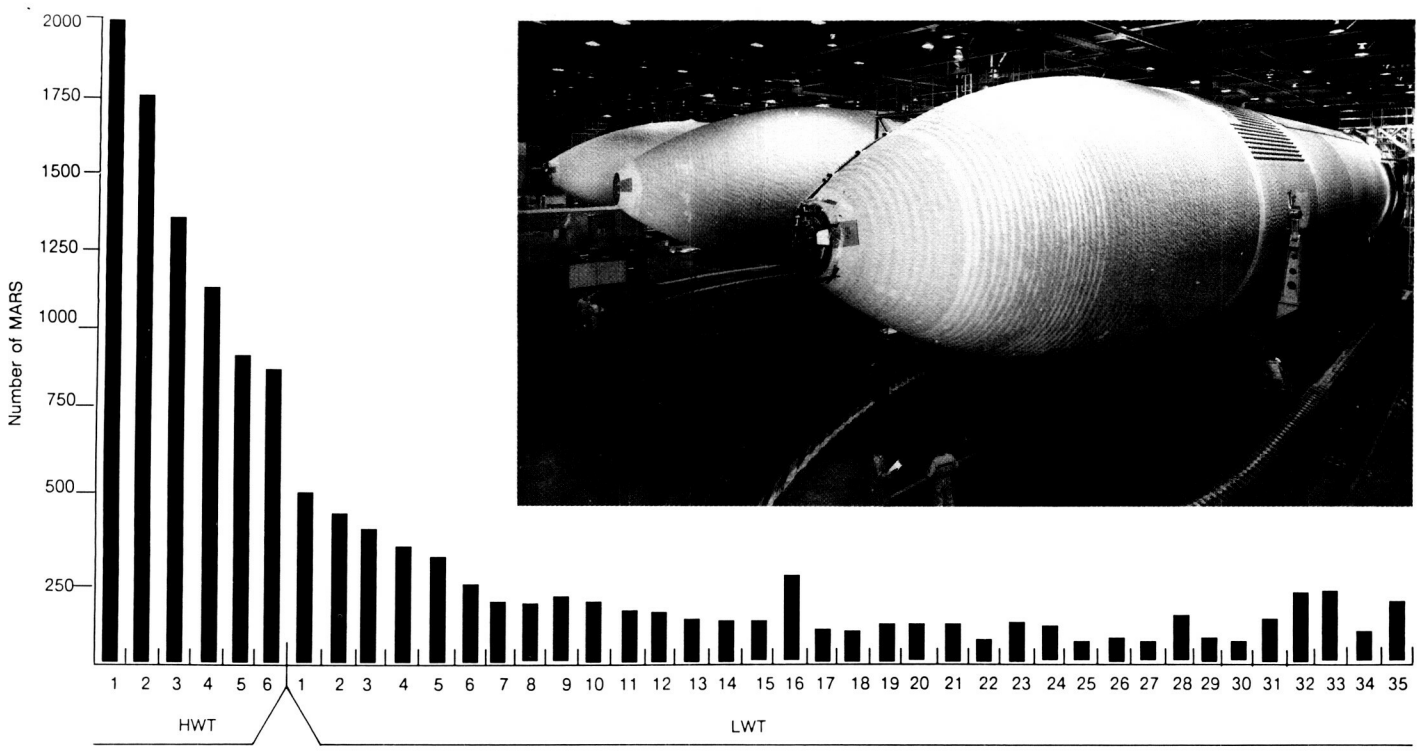


Figure 3. Nonconformance (MARS) per ET.

A Quality Ethic

Our commitment to quality is a continuing and iterative process that has become permanently integrated into our management philosophy and strategic planning. It encompasses all the functions that contribute to the engineering, manufacturing, delivery, and support of our NASA product. It includes a formalized goal and reward system which is communicated throughout the organization. More important, we promulgate our goals of high quality and continued productivity improvement to our subcontractors and vendors.

Through the diligent and continuing application of our quality and productivity improvement processes, we have exceeded the initial cost-saving goal of $66 million by more than $28 million (42%). These savings alone, when extrapolated over a mission model of 188 ETs reduced NASA's costs by more than $453 million. Furthermore, our Productivity and Quality Program activity reduced unit costs by 45% in 35 production ETs, cost of materials per unit by over 15%, and the manufacturing touch manhours per unit by 64%. This was clearly demonstrated by the cost reductions we achieved for the first 14 ETs. The accumulated savings were shared equally with NASA through funding requirements.

Through 1986 our quality enhancement processes achieved a 71% reduction in supplier nonconformances. Major nonconformances on lightweight ETs in work have decreased 81% (Figure 3) and latent defects on delivered ETs have decreased 98% over the heavyweight ET model. To this date, there have been no product recalls since the start of the program in 1973.

Our procurement activity represents more than 50% of the cost of the ET. With our positive and effective approach, we have achieved an overall 35% reduction in the price of selected purchased hardware for our fourth production buy and a $76 million savings with our fifth production buy. At the same time we attained a 47% decrease in the number of defects per vendor supplied part.

More than 2,900 managers and employees have received our Quality Circle (SRT) training. The present 95 teams at Manned Space Systems represent an outstanding 22% active participation rate. For four consecutive years we have trained and supported the implementation of NASA Employee Teams at Headquarters, MSFC, JSC, JPS, GSFC, ARC, and KSC. At Manned Space Systems, our SRTs have implemented 480 productivity and quality improvement projects.

In Summary:

Our employees' pride, dedication, and team effort for quality and productivity is exhibited by the following statistics:

- Reduced the cost of 35 production ETs by 45%
- Reduced scrap and repair 95% in 35 units
- Reduced employee turnover rate by 56%
- Reduced the number of union grievances by 35%
- Reduced manufacturing touch manhours per unit by 53%
- Reduced total support manhours per unit by 64%
- Increased savings from employee suggestions by 50%
- Increased awards to minority businesses by 136%
- Increased management training by 61%
- Maintained no lost-time accidents in 15.8 million work hours
- Maintained no product recalls in 13 years
- Received National Safety Council's highest award five times
- Received the 1985 U.S. Senate Productivity Award (State of Louisiana)
- Received the only "Award of Excellence" from the International Association of Quality Circles (1985)
- Finalist for the NASA Excellence Award for Quality and Productivity (1986)
- Awarded "Superior" rating by NASA for contract performance over the past five years
- Received the NASA Public Service Group Achievement Award for Outstanding Productivity Improvement and Quality Enhancement (1986)
- Recipient of the NASA Excellence Award for Quality and Productivity (April 1987)

Our excellent performance earned an expression of appreciation and congratulations from the NASA Administrator and the Director of Marshall Space Flight Center, and is documented in the *Congressional Record.* Our customer has acknowledged our cost-reduction efforts as superior, a fact substantiated by the Defense Contract Audit Agency (DCAA).

We are proud of the accomplishments of our people. We strive to honor our commitment to mission success, productivity, and quality excellence, which are critical to America's growth and security.

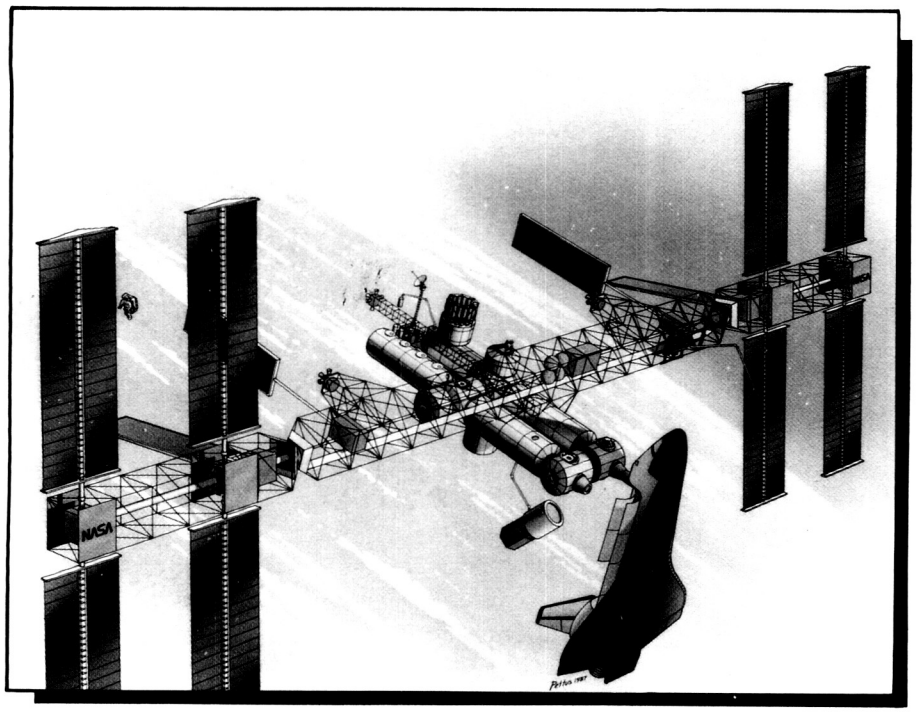
15 Steps To . . .

We have learned lessons from our PIQE program which have prompted the following 15 observations/recommendations to be followed to assure continued success:

1. Management must be dedicated to PIQE from inception to completion, and PIQE must be permanently integrated with management philosophy and strategic planning.
2. Make your customer part of the PIQE effort.
3. Disseminate PIQE objectives to all employees.
4. Communicate—and hear. We sometimes listen but do not hear.
5. Set realistic, achievable goals. High achievers rise to the challenge.
6. PIQE works best when each department or function group works with it down to the lowest level when identifying opportunities for improvement.
7. Communicate and coordinate PIQE across departments, so that a cost reduction in one department does not come at the expense of another.
8. PIQE indoctrination and training is important on all levels, but is most important for executive management.
9. The best chance for PIQE success is when the individual responsible for the improvement is also responsible for carrying it out.
10. Do not restrict PIQE measurements to human resources; include all resources.
11. Establish and maintain a reward system for successful implementation of PIQE candidates.
12. Use the subcontractor's systems wherever possible. Do not implement your system when his system is reasonable.
13. Communicate early (in the bidding phase) with the subcontractor your management's commitment to productivity and quality; commit his top management to a productivity improvement program; and continue the program with a productivity committee, progress reports, and face-to-face action.
14. Control procured hardware by contract and quality flow down to second and third tier suppliers.
15. Be generous with help where subcontractors lack depth.

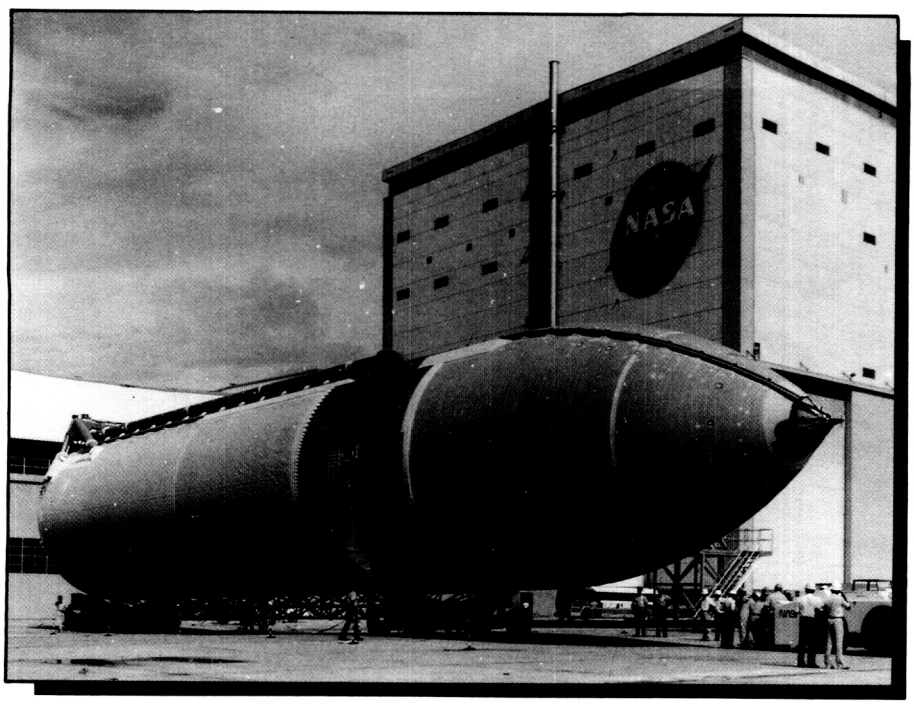
Mission Success

Through the diligent and continuing application of Productivity and Quality Improvement, we have generated significant cost savings to our customer while reducing our nonconformances. Our process is continuous and iterative. It encompasses all functions that contribute to the manufacturing, delivery, and support of our product. It includes a formalized goal-setting system that communicates division goals to the individual subcontractors and vendors. We continually plan, track, and measure performance. Our management has created and is sustaining a climate that makes mission success every employee's business in achieving the objective of improving product quality, reducing engineering and production costs, while improving the quality of work life.



"I want to tell you how proud we are of the Michoud Operations and all the things you've done to make our Space Station Shuttle Program - we couldn't do it, of course, without you guys and gals over here. You have a record to be enviable of. Everybody throughout the community looks at Michoud and wishes they could do things as efficiently and as effectively as you guys have done in the last several years."

Astronaut Jon A. McBride
Captain, U.S. Navy
Remarks to Michoud Aerospace Employees on July 24, 1986



IBM Federal Systems Division

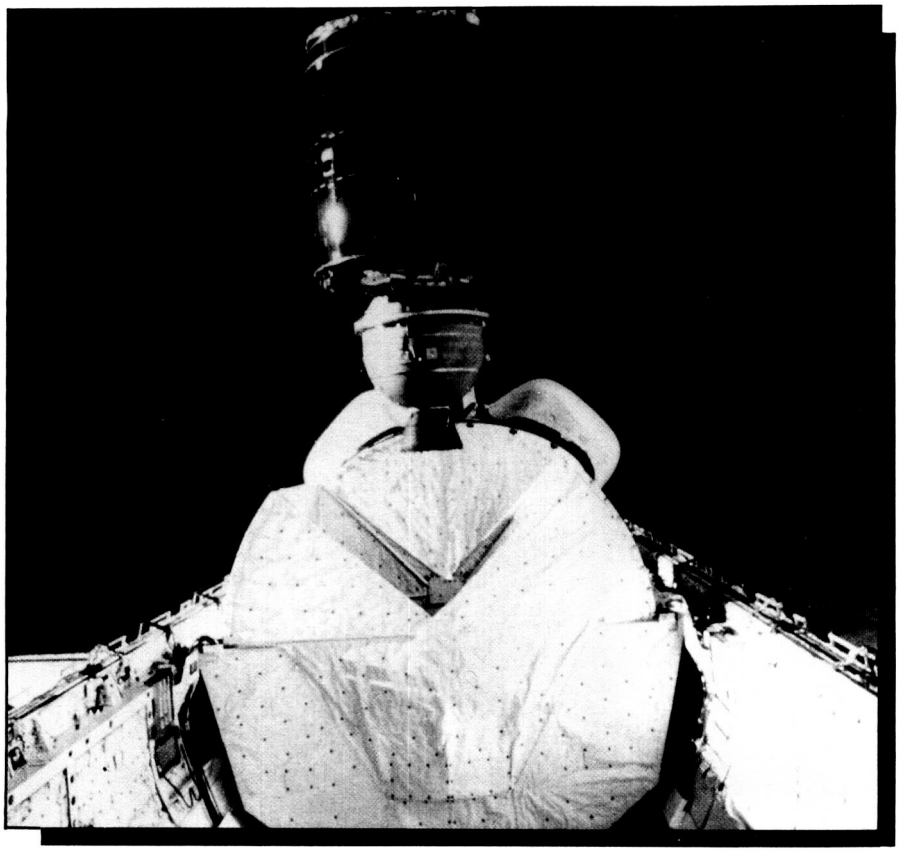
The NASA Excellence Award confirms the path we have taken in our continuing quest with NASA to produce the highest quality computer software for space exploration. From the beginning of our nation's space program, when IBM provided data processing support for the first flight of Mercury, we have set our sights on producing error-free products on time, every time.

Our software quality ethic is simple:

- Quality means conformance to NASA requirements.
- No defect is acceptable; our goal is *zero errors.*
- The work process must be well-defined and understood by everybody.
- The *causes* of defects must be removed.
- The process must be continually monitored and measured.
- Quality improvement brings productivity improvement.

Sometimes "zero defects" seems like an elusive goal. But this award demonstrates that the goal is achievable; that improvements and new techniques can and should be carefully evaluated, tested, and used; and that our dedicated people are the driving force behind our quality achievements.

Gerald W. Ebker
President
IBM Federal Systems Division



Space truck. A satellite leaves the baby of the space shuttle. IBM software manages payload deployment.

For more than 30 years IBM data processing systems have helped push back the frontiers of space. IBM computer hardware, software, and system integration services have been used in every NASA manned space flight program since Mercury. The IBM Federal Systems Division in Houston received the 1986 NASA Excellence Award for Quality and Productivity for the outstanding quality of its flight software, which guides, navigates, and controls the Shuttle from launch to landing.

The IBM Federal Systems Division provides hardware, software, and integration services for large, complex data processing systems used by the federal government and private industry. In the federal government these systems operate in ships, submarines, aircraft and spacecraft, and in ground-support facilities. For private industry the Federal Systems Division has developed a travel agency management system, point-of-sale systems, hospital data processing networks, and blood, chemical, and laboratory analysis systems.

IBM established the Federal Systems Division in Washington, D.C., in 1955 to serve the national interest. Within a few years the young division began helping America's space program get off the ground. In 1957 an IBM system helped predict the orbital paths of the pioneer flight of Vanguard I, and in 1958 an IBM system computed tracking and control information for the first flight of Mercury.

The Division moved to Houston with NASA in 1962 to develop a ground control system for NASA's Real-Time Computer Complex, the forerunner of today's Mission Control Center. This very large ground-based data processing system was the primary flight command and control center for subsequent Gemini, Apollo, Skylab, and Space Shuttle missions.

IBM systems have flown aboard almost every American manned spacecraft. For example, IBM provided the onboard data processing system for Gemini spacecraft and developed the Saturn Instrument Unit that helped guide Apollo astronauts to the moon.

Today IBM computer systems are used in virtually every part of the Space Shuttle Program. IBM helped develop the Launch Processing Center at Kennedy Space Center, the Mission Control Center at Johnson Space Center, and the primary avionics system onboard the orbiter. Since 1975 IBM programmers in Houston have developed more than 9.5 million lines of software code to support Shuttle mission objectives.

The IBM Quality Philosophy

IBM has a long-standing commitment to service and excellence. Decades ago, IBM's founder, Thomas J. Watson, narrowed the company's operating philosophy to three basic beliefs: respect for the individual, the best customer service in the world, and the pursuit of excellence in all tasks.

These beliefs continue to guide the company and its Federal Systems Division. They form the basis of our relationship with NASA.

Figure 1 photo: Shuttle astronauts receive continuous updates on the status of the craft from IBM displays. Data are generated by a half million lines of virtually error-free IBM software that guides, navigates and controls the Space Shuttle in flight.

IBM Onboard Software: Critical to NASA Space Shuttle

The IBM Federal Systems Division in Houston provides data processing systems to NASA both on board the orbiters and on the ground. The IBM Shuttle Primary Avionics Software Subsystem is vital to maintaining mission safety and meeting the objectives of this important national program. The IBM onboard system guides, navigates, and controls the orbiter during every phase of flight. It constantly monitors and maintains the orbiter's major systems, including payloads, and continually provides up-to-date data on the status of the craft to the crew on cockpit displays (Figure 1).

IBM has been developing onboard software for the Shuttle Program for nearly 15 years—from the Approach and Landing Test Program, to the Orbital Flight Test, to the operational phase. The base system for the operational phase was delivered in 1981.

The job of developing onboard software is especially challenging because of the complexity of the avionics and data processing systems, the sheer amount of software, stringent reliability requirements, and the need to support all phases of the flight.

The IBM onboard Primary Avionics Software System consists of three major products: the base flight software system (generic algorithms and sequences used to control and monitor the Shuttle), reconfigured flight software systems (which include mission-unique flight data that change from flight to flight), and supporting software necessary to develop and reconfigure the software. In recent years IBM has improved the quality and productivity of all three products.

The IBM onboard software runs on a set of four redundant IBM AP101B computers, which operate simultaneously during critical phases of the flight. Each computer contains 106,000 32-bit words of main memory (Figure 2). The software occupies eight overlays of memory to support the flight. In addition to controlling all avionics functions on board the

orbiter, it also is used to support NASA research and development activities.

Since 1974 IBM has developed more than 0.5 million source lines of code for onboard software and more than 1.7 million lines for development and reconfiguration support. Our support software is used to develop onboard software, reconfigure flight software, and manage the entire process.

IBM is continually adding new requirements to the system at NASA's request. The process of developing new software for an already existing system involves analysis of all the software changes, configuration management, the creation of baselines, software development, software system build, independent verification, and field support.

More than 300 IBM employees in Houston support the development of the Shuttle's onboard software. All work is done at individual terminals on-line with NASA software development and production facilities consisting of mainframe computers, actual IBM onboard general purpose computers, and interface equipment (Figure 3).

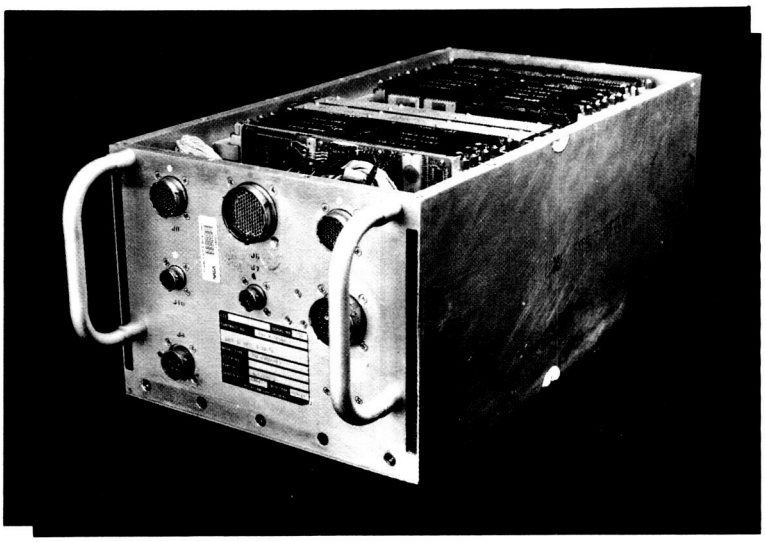


Figure 2 photo: IBM's Shuttle flight software runs simultaneously on four redundant IBM computers during ascent and descent, a NASA requirement that adds safety and complexity to the Shuttle onboard data processing system.

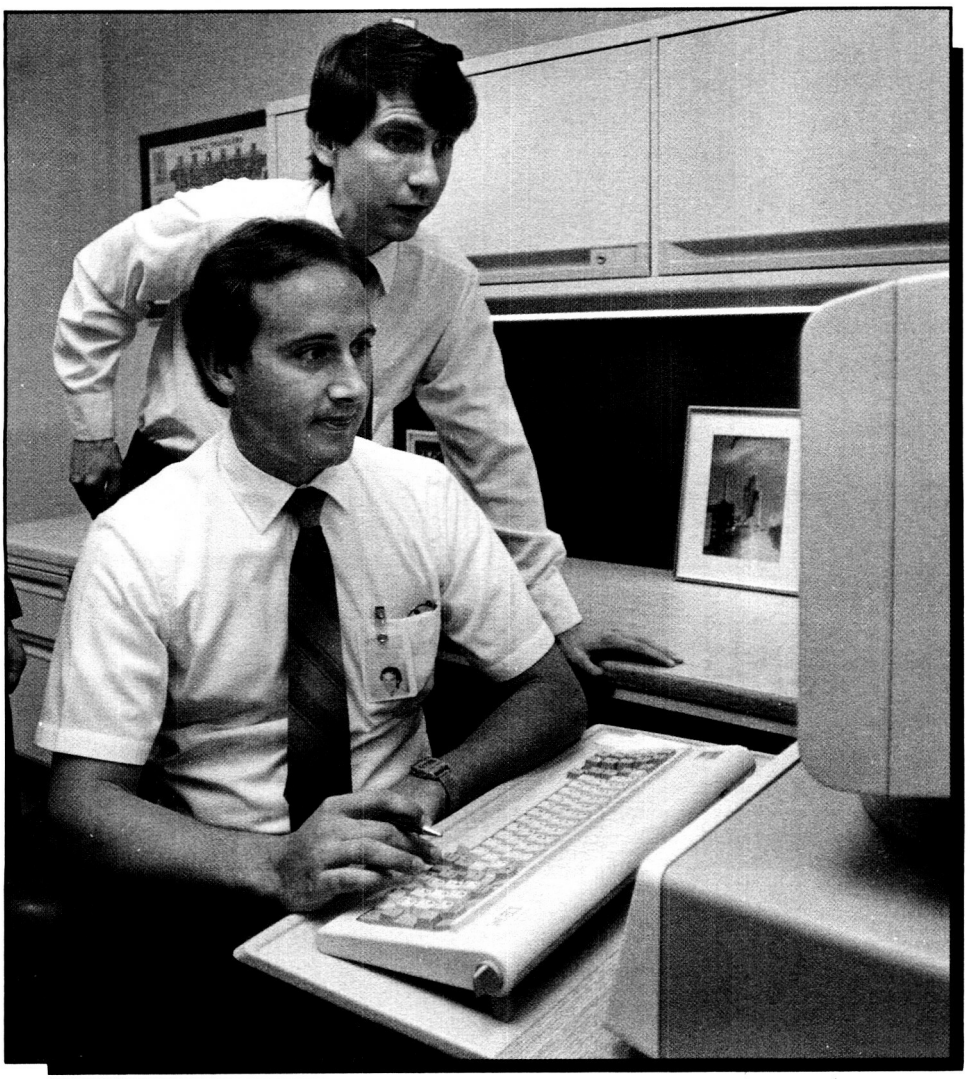
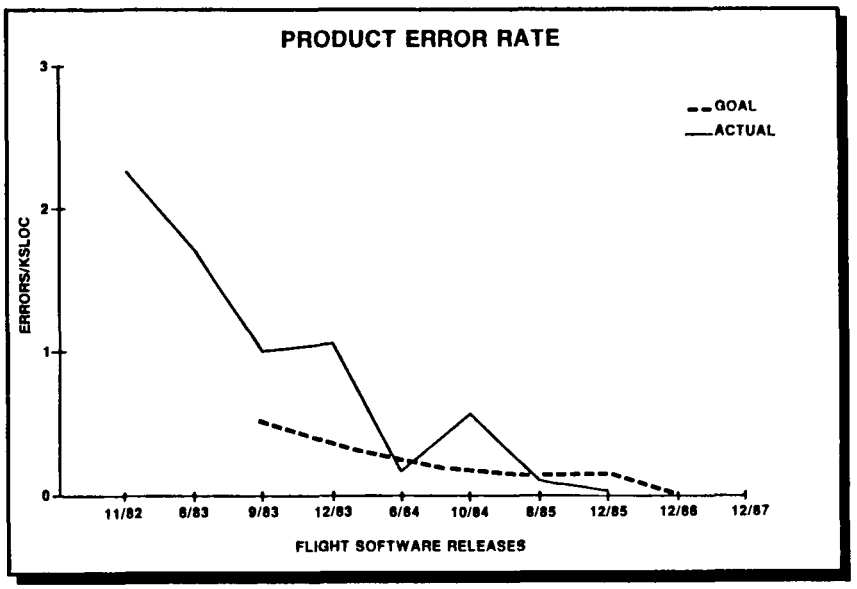


Figure 3: Employees have individual workstations with direct access to NASA software development and production facilities.



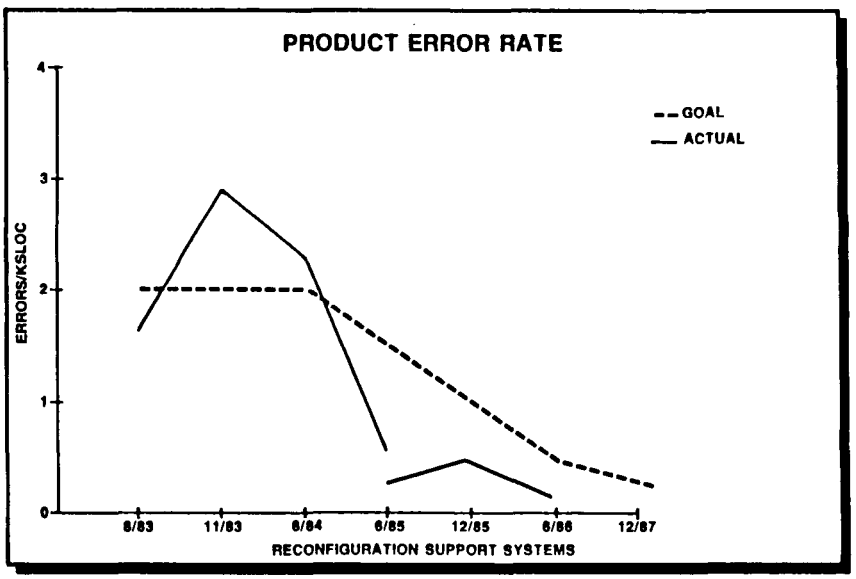


Figure 4: From 1982-85 IBM reduced onboard Shuttle software defects from 2.0 to 0.11 errors per thousand lines of code (KSLOC).

Software Quality and Productivity Measurements

The quality of reconfigured software systems, which are highly critical to flight, is monitored especially closely. The released product error rate that we monitor is the number of errors in reconfiguration data per delivered system released to the user.

$$\text{Released Product Error Rate} = \frac{\text{Discrepancy Reports (DRs) Found After Release}}{\text{Released System}}$$

Potential users include NASA scientists and engineers, astronauts, and other NASA contractors.

To be considered an error a discrepancy must either (1) require a software fix, (2) require NASA to waive the requirement under which the software was developed, or (3) require documentation for the user.

This is considered a stringent measurement, since early software releases may be used in NASA laboratories or in the field before testing is complete.

The quality of onboard software also is measured in errors per thousand lines of source code (KSLOC). These errors are measured from the point of software certification after testing is complete.

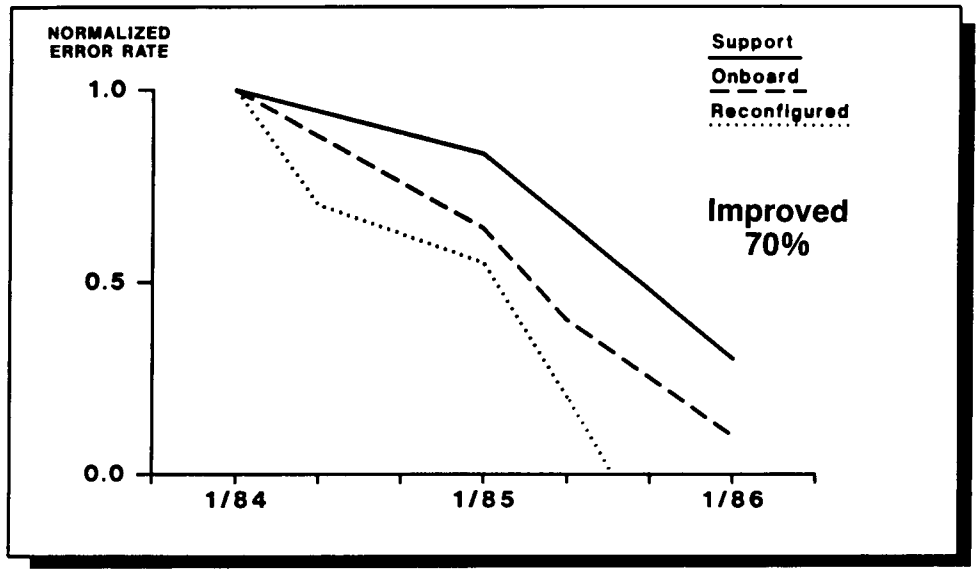


Figure 5: By carefully monitoring and managing the software development process, IBM reduced product errors for three types of software by 70 percent.

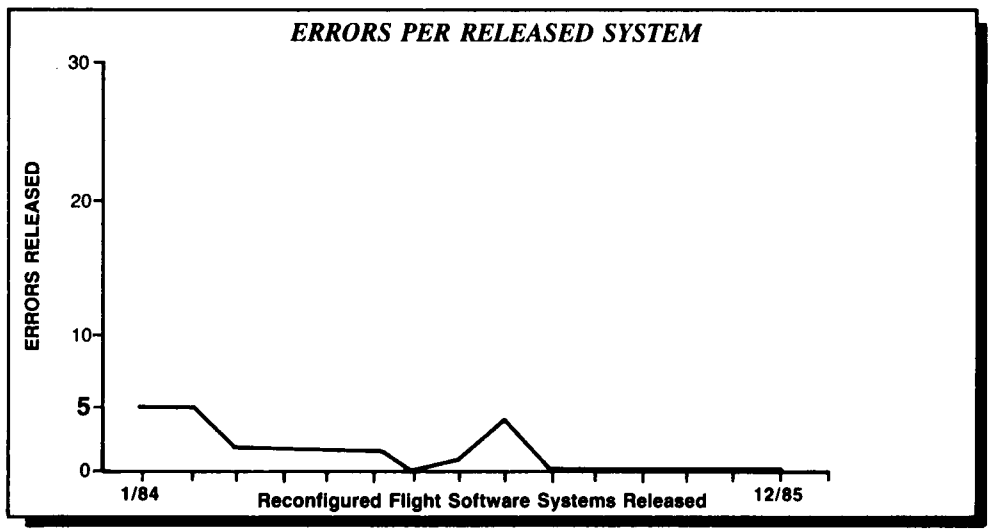


Figure 6: The last six reconfigured Shuttle flight software systems produced by IBM in 1985 contained no errors.

$$\text{Product Error Rate} = \frac{\text{DRs Found After Software Certification}}{\text{KSLOC}}$$

The product error rate for onboard and reconfiguration support software is monitored for each release (Figure 4). Since 1984 product errors for the three types of software (base software, reconfigured code, and support software) have decreased 70 percent (Figure 5). In fact, reconfiguration errors for software in the last six systems delivered in 1985 were completely eliminated (Figure 6). From 1982 to 1985, base source code error rates decreased from 2.0 to 0.11 errors per thousand lines of code for onboard software and from 3.0 to 0.4 errors per thousand lines of code for support tools — making the quality of IBM's onboard Shuttle software among the highest in the industry.

The effectiveness of the IBM software development process is monitored by two measurements that focus on source code: the percent of errors found early in the process and the process error rate. Separate measurements are tracked for each release of the flight software and are monitored in conjunction with product error rates. Specific goals are established for each measurement to realistically approach the ultimate goal of zero defects. The first measurement, percent of errors found early, focuses on finding errors early in the development process.

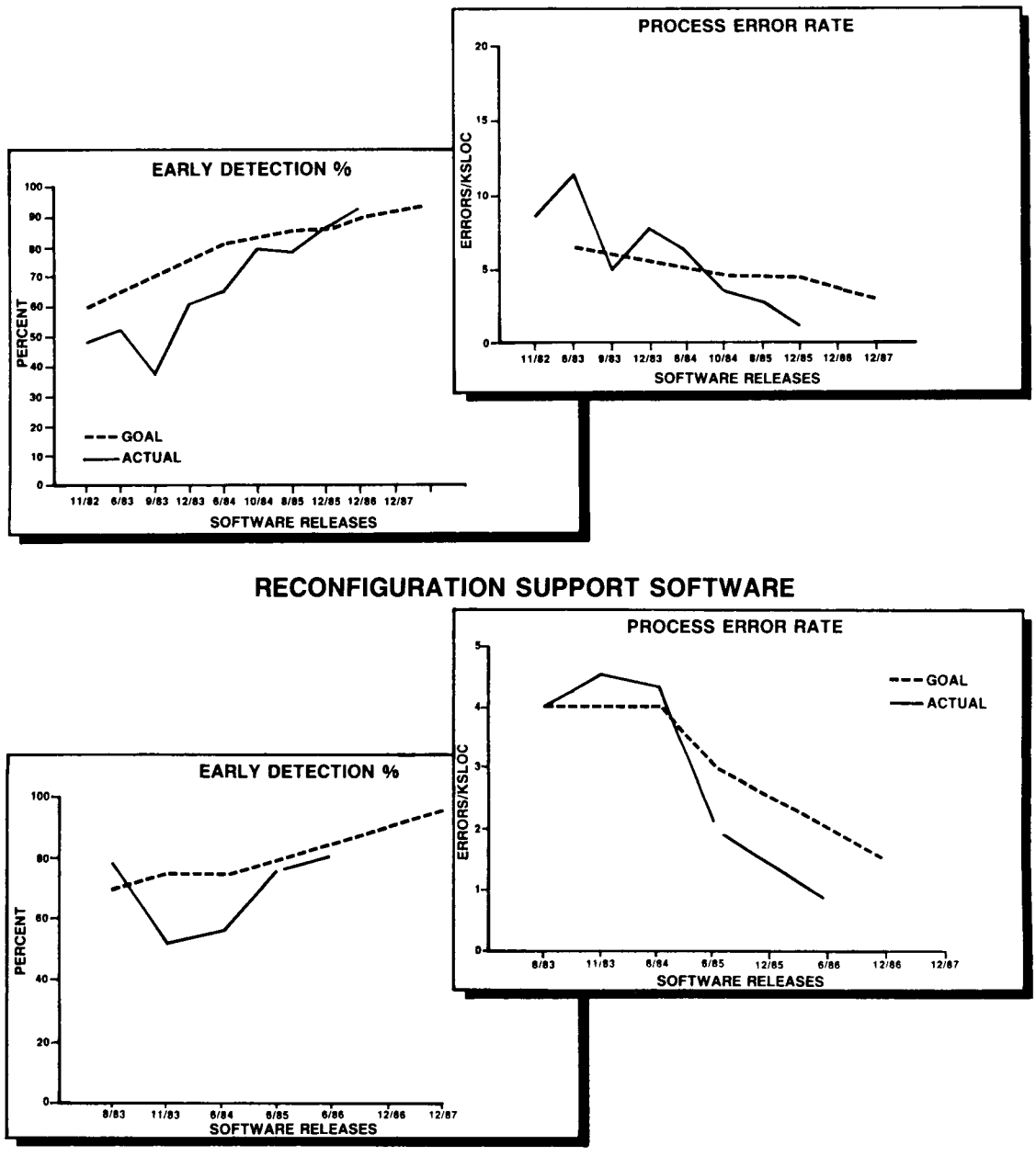


Figure 7: From 1982 to 1987 IBM significantly increased the number of errors found early in the software development process and decreased the number of errors found before product release.

The early detection measurement is defined as:

$$\text{Early Detection \%} = \frac{\text{Number of Major Inspection Errors} \times 100}{\text{Number of Major Inspection Errors} + \text{Valid DRs}}$$

A major inspection error is any error found in inspection that would have produced a discrepancy report if undetected. Discrepancy reports document any software error found after the software enters a controlled environment.

The second measurement, process error rate, is defined as:

$$\text{Process Error Rate} = \frac{\text{DRs During Development}}{\text{KSLOC}}$$

Ground software process error rates are counted until the software is released; flight software process error rates are counted until the NASA Software Readiness Review (SRR). By the time of the SRR, IBM has completed testing and certifies that the product is ready for use on a specific Shuttle mission. (After SRR, errors are counted as product errors.) Error rates are measured per thousand source lines of code (KSLOC). From 1982 to 1987 IBM increased the early detection rate and decreased the process

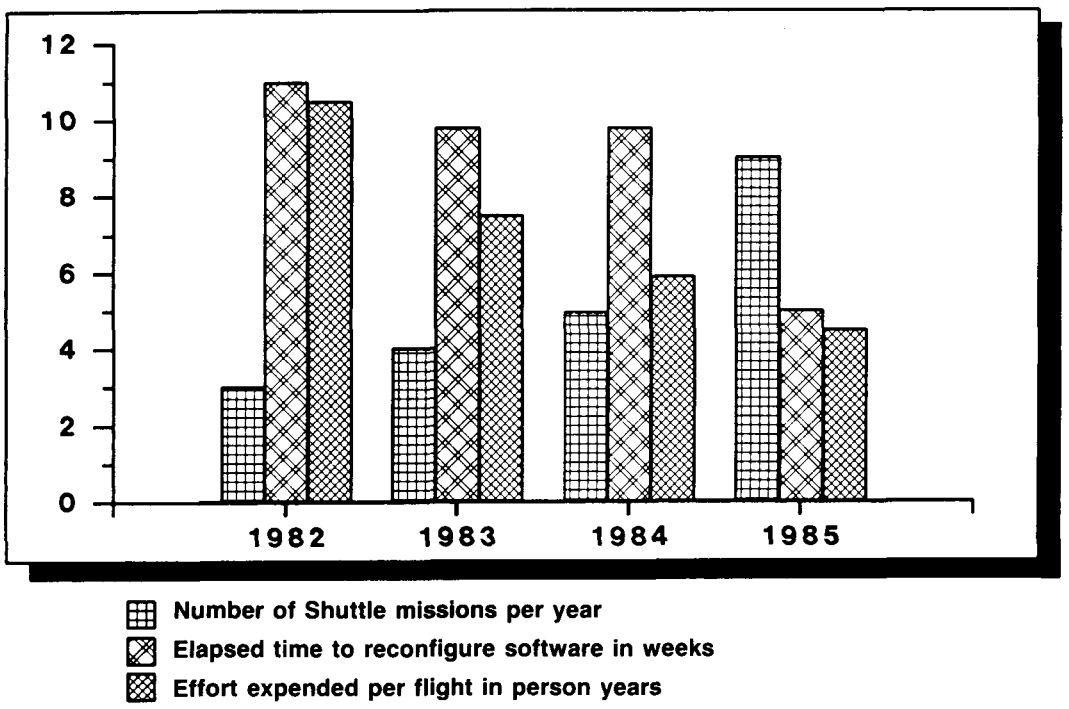


Figure 8: To improve productivity, IBM consolidated skills, increased its use of subcontractors, and automated the software development process.

error rate for onboard primary avionics software and support software (Figure 7).

In addition to monitoring error rates, IBM continually reviews organizational structures and individual job assignments to find ways to cut costs and improve quality. For example, in mid-1983 it became apparent that we needed to become more efficient in order to respond to the Shuttle Program's increasing flight rate. We consolidated skills, increased our use of subcontractors, automated the process more, and increased the quality of the delivered product. We cut in half the time and effort needed to reconfigure the flight system (Figure 8), yet at the same time reduced errors to zero for the last six systems released.

To improve quality and productivity, we automated the process and now use software tools at every stage of development. We developed an on-line software tool to track the progress of requirements through the review and approval cycles. It is so effective that it is now used by NASA and other Shuttle contractors. We developed other software tools to collect quality and productivity data automatically for better process control. We increased the number of workstations from one for every two employees in 1983 to well over one for every single employee today. We also greatly increased the percent of intelligent workstations (Figure 9).

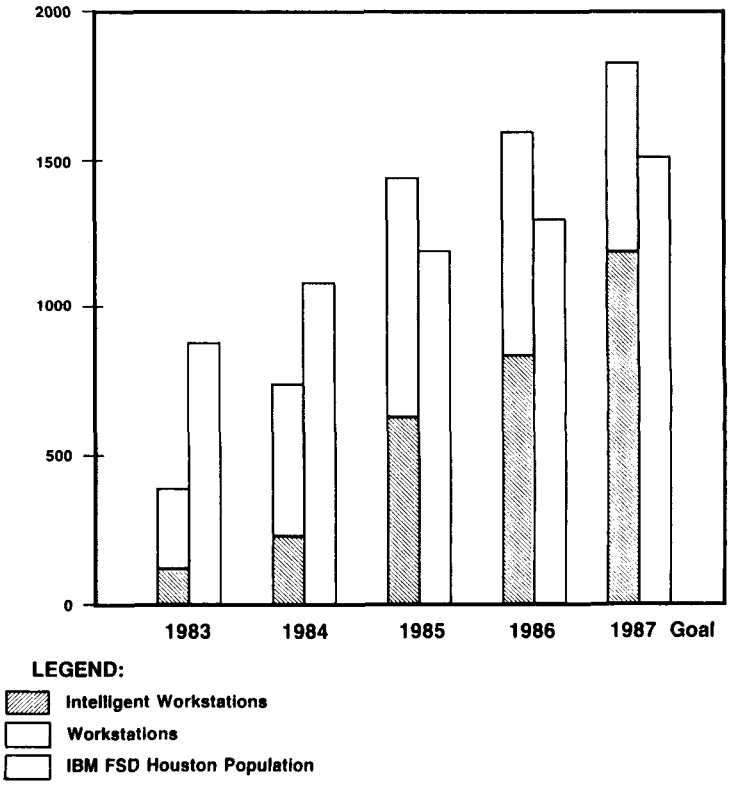


Figure 9: To increase the productivity of employees who reconfigure Shuttle flight software at its Federal Systems Division facility in Houston, IBM increased the number of workstations and intelligent terminals at the site.

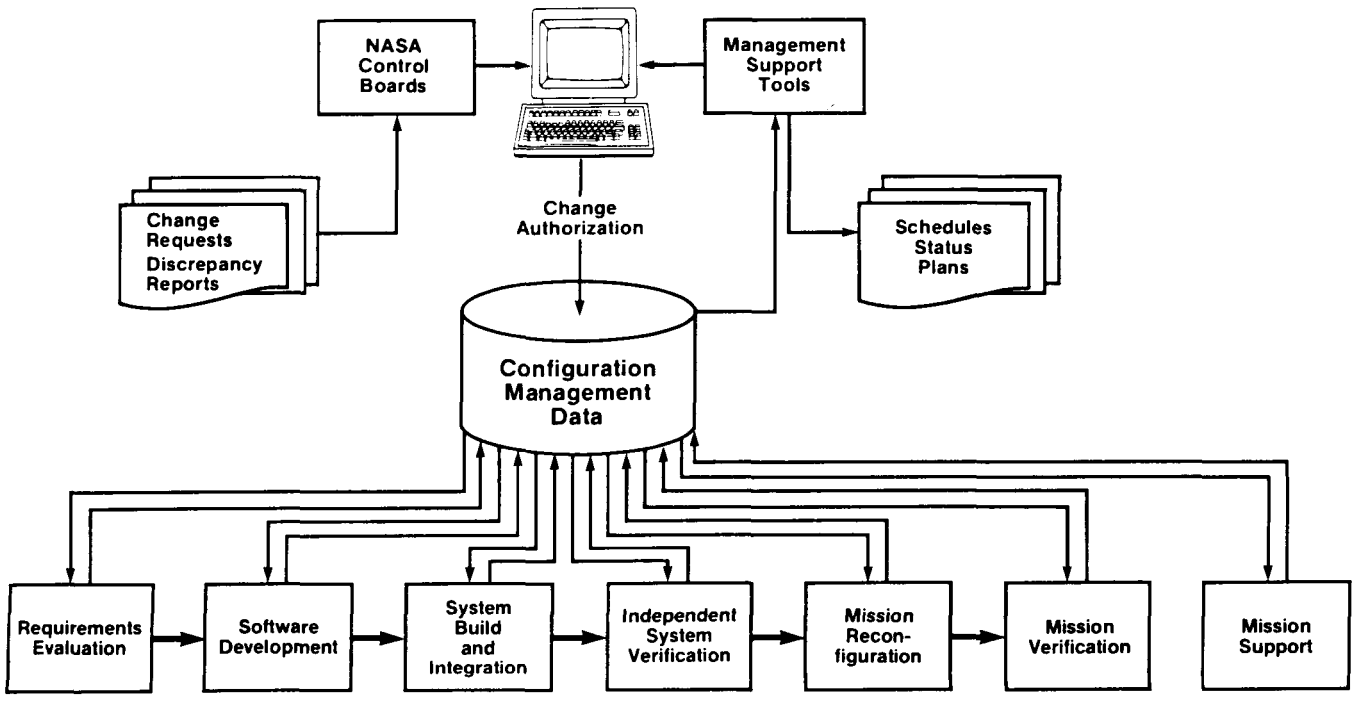


Figure 10: IBM employees continually monitor the software development process electronically from information contained in the IBM Configuration Management Data Base.

Software Development Process Emphasizes Quality

Because the IBM flight software is critical to the operation of the orbiter and the safety of the crew, our goal is to produce software that is completely error-free. Our primary objectives are:

- to develop software that adheres to the letter and intent of NASA's requirements;
- to ensure that the software performs in accordance with NASA's operational expectations for nominal and off-nominal situations;
- to provide software that is error-free.

We consider quality assurance the individual responsibility of every IBM employee and manager. The IBM Federal Systems Division has comprehensive Quality Assurance Directives. Our Quality Plan is tailored to NASA's program requirements and involves rigorous standards, comprehensive and integrated test plans, tests, audits, and inspections of the work products at key control points within the process, as well as configuration control of onboard and support software and statistical control of the software development process itself. An independent quality assurance organization monitors and audits for compliance to the contract and IBM Federal Systems Division Quality Assurance Directives.

The key to our software development quality improvement program is rigorous requirements definition, well-defined software engineering standards, independent verification, and defect-cause analysis and removal (Figure 10).

In July 1984 we extended our quality enhancement effort as early as possible in the process by inspecting

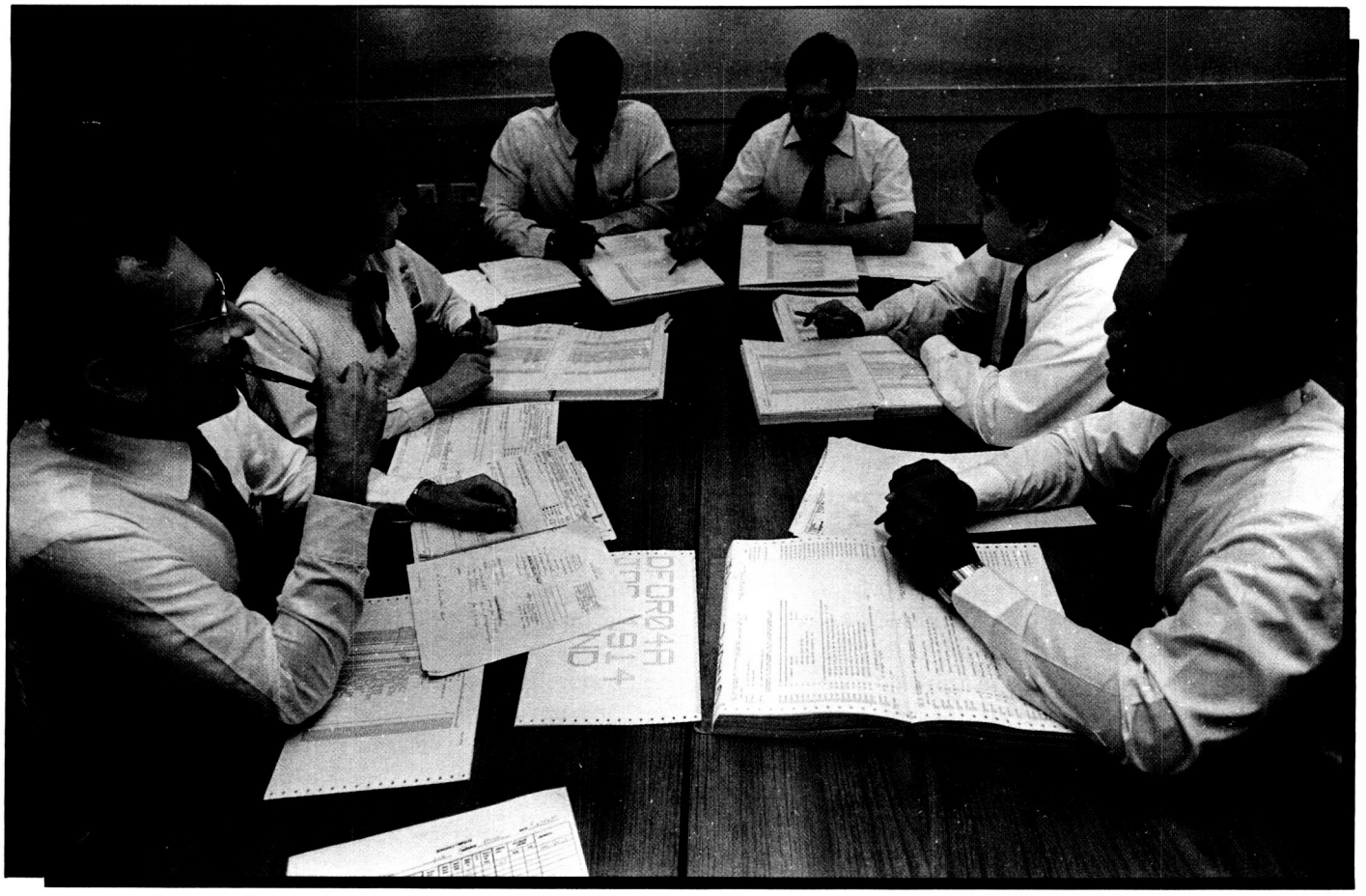


Figure 11 photo: Independent inspection teams inspect software under rigid, formalized procedures that require the use of checklists and highly accurate software tools.

all requirements for completeness, accuracy, and intent, which helped prevent errors in the software. We also extended our quality efforts after delivery with aggressive field support to help users understand the product better.

We also monitored products for defects at key control points in the process. All defects detected at each checkpoint were noted, analyzed, and the process changed whenever possible to prevent their recurrence. During that time we maintained extensive communication with our NASA customer to ensure that our quality efforts were not interfering with our ability to respond to the Shuttle's increasing flight rate.

Our defect prevention and early detection efforts clearly paid off. From 1982 to 1986 the number of errors inserted in onboard software development process decreased significantly while the percent of errors found before delivery increased.

We put more emphasis on software engineering, including top-down, structured software development methods, well-defined and documented standards, and stringent process control to assure the consistent application of these standards and methods across the software life cycle.

Our standards demand technical reviews, formal inspections, and software configuration control. The FSD Software Engineering Council, made up of the top-ranking software executive from each location, has final approval over these standards. We train both management and employees in IBM FSD software and systems engineering methods and update our education program as technology changes.

The inspection process was made as well-defined and controlled as the development process. We extended inspections to peripheral parts of the

process, such as the design and development of software test cases. The prevention of errors in test cases saves staff time and computer resources. All parts of the software development and test process benefit from doing it right the first time. Currently we inspect requirements, functional and detailed designs, code, documentation, test plans, test cases, and test results. The process of identifying and recording errors is formalized, rigorous, and highly developed. In a data base, employees record the length of the inspection, the number and types of errors found, the severity of the error, and inspector who discovered the error. All inspections are conducted with checklists and software tools. Present at each inspection is the employee who developed the code, his or her peers in the work group, an independent verifier, a requirements analyst, and a moderator (Figure 11). Attendance is mandatory. All errors or issues are documented and tracked to resolution. Inspection error information, coupled with discrepancy report information in the Configuration Management Data Base, make defect cause and trend analysis extremely efficient.

Our policy of independent software verification is one of the most important factors in our successful development of error-free software. Our verification organization maintains a healthy adversary relationship with the development organization. It is actively involved in every phase of the software life cycle. It operates on the assumption that requirements are not infallible and that the software has not been previously tested. All discrepancy reports are assumed valid until analyzed — that is, the software is assumed to be in error until verification procedures show otherwise. The purpose of the testing process is to verify that the code performs to the letter and intent of the requirements.

After each software package is released to NASA, we review error information again. Our post-release error analysis and recommendations focus on prevention first and detection second. An independent verification team conducts two separate reviews to determine (1) how the error can be detected by testing and (2) how the error can be prevented in the first place. We conduct this "oversight error analysis" across the entire software development process (from requirements analysis through final testing) to determine how we can improve every step of the process. The project manager conducts quarterly reviews of error statistics; measurements are reviewed by the FSD general manager twice a year. Other periodic reviews are conducted at lower levels all the way from first-line managers to the project manager.

Periodically we reanalyze groups of discrepancy reports without regard to previously determined and documented categories. This fresh look at error trends helps us change existing procedures or develop new ones to prevent the recurrence of even the subtlest errors. For example, one study showed that errors were more prone to happen with display functions. As a result, we put special emphasis on the display area, educated programmers to the problem, and subsequently reduced errors of this type.

This constant monitoring of the documented software development process, emphasis on error prevention, and focus on "doing it right the first time" have helped us increase errors found early and decrease errors overall. More than 80 percent of errors are now found before the software is built. Error rates have been reduced to less than 0.2 per thousand source lines of code.

Quality Improvement Results in Productivity Improvement

From 1983 to 1985 IBM's actual costs for onboard Shuttle software ran 4 percent under NASA's budgeted cost — during a time when IBM was required to respond to frequent requests for software changes and Shuttle mission reschedulings. Though NASA budget and cost constraints required that our programming population be reduced to critical skill levels in all areas, NASA's request for software changes remained high. From 1981 to 1985 we reduced the IBM onboard flight software code programming population 40 percent from more than 160 to 101 and implemented more than 4,000 software changes. We accomplished this by documenting and standardizing the software development process, forcing error identification earlier in the process, developing a well-defined testing methodology, and automating parts of the code production and testing processes.

We also accomplished significant reductions in the cost of reconfiguring flight software during the same period. In 1981 we separated the process of developing new software capabilities (or code changes) from the process of reconfiguring flight information (data changes). Automation reduced manpower costs, lowered the skill level necessary to do the actual reconfiguration, and improved the quality of the final product. We developed support software and data processing facilities to standardize the process and ensure the quality of reconfigured software.

In 1984 we focused on reducing turnaround time for reconfiguration and modified the flight software code to allow even more automation. We built a software reconfiguration production line using commercial software products and eliminated the need for human intervention. We formed a reconfiguration system engineering group to integrate onboard and ground configuration methods. NASA evaluations throughout the 1983-1986 period credited IBM for "continued excellence in cost management and contract administration."

Management, Employee, and Subcontractor Involvement

Quality improvements like these are no accident. They are the result of a six-point quality ethic that both management and employees are committed to put into action:

- Quality means conformance to NASA requirements.
- No defect is acceptable; our goal is *zero* errors.
- The work process must be understood and well defined.
- The *causes* of defects must be removed.
- The process must be continually monitored and measured.
- Quality improvement results in productivity improvement.

Our management's commitment to quality is easily seen in our well-documented policies, management participation in reviews at every level both inside IBM and at NASA, dedication of human resources to quality improvement projects, and capital investment in physical facilities, equipment, and programs for employee well-being. The FSD Houston facility is equipped with the latest and most technologically advanced office automation equipment through which employees communicate electronically to NASA, to one another, and throughout the world. IBM top management actively participates in conferences and forums with NASA to improve the quality and productivity of the entire NASA team.

Management's commitment is mirrored in the work force. Four times a year, each onboard software employee is evaluated against an individual performance plan, which he or she helps write. Quality improvement and cost effectiveness goals are included in most employee performance plans. Frequent two-way communication between management and employees encourages suggestions and improvements. This includes day-to-day consultation, department information flow meetings, work group meetings, and — in the case of software development—design and code inspection team activities. In addition, each first-line department has a formal quality improvement plan with measurements that are reviewed by management all the way up to the program manager.

One hundred percent of our employees at the site participate in the quality improvement process. Measurements for a business area are tracked in the site's Strategic Operating Plan. We conduct opinion surveys of all employees at least every two years; several questions on the survey deal with employees' perception of quality. Regular measurement reviews with employees and management provide feedback on how well we are doing compared to our plans. Pay increases and promotions are based on performance evaluations. Cash awards and mementos are given to individuals and work teams for quality improvement and cost effectiveness.

IBM selects subcontractors on a competitive basis and prepares statements of work that contain specific quality and productivity performance criteria. We encourage two-way communication with our subcontractors and reward performance based on compliance with the statement of work. Award fees are paid in direct proportion to performance throughout the life of the contract to motivate continued excellence as well as schedule and cost performance. We make it clear to subcontractors that we award follow-on contracts only to companies which provide superior performance within cost targets. Subcontractors know their work scope may expand if their performance merits it. To encourage outstanding performance, we present an annual award to recognize the best subcontractor for the previous year. The award is presented at the subcontractor's place of business to encourage employees and is publicized within IBM as well.

Summary

IBM has improved both the quality and productivity of software and services delivered to the NASA Shuttle program. IBM's onboard Shuttle software has never had an in-flight error that affected crew safety or prevented the accomplishment of mission objectives.

IBM has met and anticipated the ever-changing needs of the Shuttle program and delivered products of the highest quality within the customer's cost and schedule constraints. Quality assurance, reporting, communications, and problem resolution processes — developed and improved at the IBM Federal Systems Division in Houston — have made these successes possible. We monitored and improved the quality of the in-plant process as well as the delivered product.

The success of our quality and productivity improvement program is reflected in our record: zero reconfiguration errors for the last six delivered systems and 0.11 errors per thousand source lines of code. We were able to deliver quality reconfigured systems in less time and at lower cost while responding to frequent customer changes.

We achieved this improvement through the concerted effort of both employees and management in a positive and highly motivated work environment. All levels of management and employees are committed to the quality improvement process. We have integrated quality improvement methods into the work process. We set goals, measure performance, analyze results, and implement process improvements. Our policies of open communication, commitment to quality, and a common dedication with NASA to the Shuttle program have made these accomplishments possible.

Theme 1

Challenge for the Competitive Edge: Responding to Competitive Pressures

Competition. It spurs us on to greater achievements. It helps us to reach down deep and increase our effort. Under its influence we are capable of producing more than we ever thought possible. When a business or industry is spurred on by competition, it looks for ways to improve its product, cut its price, produce more efficiently, deliver its product more quickly. When this starts happening, everyone benefits. Competition is the catalyst for progress.

The two recipients of this year's NASA Excellence Award for Quality and Productivity, Martin Marietta Manned Space Systems located in New Orleans and IBM Federal Systems Division located in Houston, thrive on competition and have made tremendous advances in their respective fields.

Martin Marietta's response to NASA requirements was not accidental, but was due to a well planned and coordinated effort. One of their principal tools was their eight volume Production Readiness Plan which covered every aspect of quality enhancement and productivity improvement. As a result of their efforts, Martin Marietta has created a Mission Success culture with the mandate to accept nothing less than error-free performance on every level of its operation.

IBM Federal Systems Division is also a strong competitor. They have responded to their challenges by forming new partnerships with customers, by introducing new products and services, excelling in quality and innovation, and by streamlining their business processes for greater efficiency. The story they tell in this book is marked by efficiency and thoroughness from top to bottom. It has made them a world leader and worthy of emulation.

Theme 2

Make a Management Commitment to Quality and Productivity: Leading from the Top

The old childhood game of Follow the Leader. We all played it. But little did we know when we led our classmates all over the school yard that we were learning a valuable lesson about human nature — a lesson that has an application for us today. People will follow a leader, especially if that leader inspires confidence and has a clearly stated goal. Today, as adults in the serious business of producing products of the highest quality, we would do well to remember that old childhood game. If we, as managers of people, show by our actions that we are committed to nothing less than the highest quality and the greatest productivity, then that's exactly what we'll get.

The two recipients of this year's NASA Excellence Award have made great strides in both quality and productivity and it all began with leadership from the top.

In 1978 the CEO and Chairman of the Board of the Martin Marietta Corporation, Thomas G. Pownall, announced a quality and productivity policy. The figures included earlier in this publication tell the story of the remarkable progress Martin Marietta has made. Once the program was articulated by top management, employees made it their goal to put it into practice and make it work. Each department was assigned goals as a percentage of improvement committed to its customer. In addition, a productivity integrator was put in charge at the top management level to coordinate the commitment and to develop long-range plans for continued improvement. The success of the program has been phenomenal.

IBM's story is a similar one. Its management has in place a comprehensive program of reviews at all levels designed to closely monitor the company's progress towards its quality goals. Twice a year the IBM vice president of quality reviews improvement progress of each operating unit of IBM. Four times a year the Federal Systems Division (FSD) director of quality reviews the progress of each location in the FSD. Once each month the general manager of FSD reviews the quality progress of one business area reporting to him, and conducts a full review of all business areas twice a year. In addition, management has reinforced its commitment by allocating capital to improvements in facilities, office equipment, and communications. And finally, the corporate structure of IBM includes a vice president of quality, directors of quality at each operating unit, coordinators for quality at each FSD location and business unit, and quality councils that assist management in implementing the quality improvement process.

Theme 3

Mesh Goals and Responsibilities: Opening Two-Way Communications

Theme 2 addressed the issue of leadership, but Theme 3 comes to the heart of how a leader brings his goals to fruition. A CEO can compose reams and reams of lofty goals and principles, but unless he communicates them to his employees, they remain only words on paper and are never put into practice. But communication isn't a one-way street; top management needs to afford employees the opportunity to comment, to make suggestions, to offer counsel on the specifics of the task, for they are the experts in the day-to-day, hands-on aspects of the job. Failure to take into account their expertise is a waste of one of the most valuable resources any manager has — the employee's detailed knowledge of his job.

The president of Martin Marietta Manned Space Systems observed that "When our quality and productivity efforts are included and communicated throughout the entire Michoud Organization — all departments and their operations — and our major subcontractors and vendors — it will then represent a genuine approach to improvement." That approach includes the weekly downward communication of goals, strategies, and objectives through the Productivity Committee. Problems and results are communicated upward during this same meeting and bi-weekly during the vice president's "Blue and Brown Book" meetings. Not only does management at Martin Marietta listen, it responds. In 1984, 89 percent of Martin Marietta's employees responded voluntarily to a detailed survey and the results were fed back through small group meetings and through various media to the entire company. The results of these meetings were the development of 495 action plans, of which more than 90 percent are now complete.

At IBM, the following highly structured programs assure a steady flow of both upward and downward communications: yearly performance planning, counseling, and evaluation of each employee; skip-level interviews between an employee and a higher-level manager; information flow meetings and electronic newsletters; frequent department meetings; working groups or teams across departmental lines; an open-door policy; a Speak Up Program wherein employees are able to write their concerns to management anonymously; bi-annual employee opinion surveys; and various other vehicles of written communication.

One of the keys to the years of success enjoyed by both Martin Marietta Manned Space Systems and IBM has been their recognition of the critical importance of communications between management and employee. When everyone involved clearly understands what needs to be done and is encouraged to bring his expertise to bear on the problem, great things begin to happen.

Theme 4

Make Innovation Rewarding: Encouraging Innovation and Risk-Taking

Innovation, long the hallmark of American industry, seems today to have taken the backseat to conservatism and caution. Too many companies have developed the habit of waiting to see what the competition does before sticking out their own corporate necks. When it's time for budget cutting, R&D is among the first to go. With that kind of approach the best they can ever hope for is to come in second. Fortunately, that approach is not universal. There are still some companies that forge ahead, developing new techniques, experimenting with new approaches. The only time they look back is to see how far they've left the competition behind.

This year's two recipients are leaders for that very reason: they look ahead. They encourage their employees to think, to analyze, to offer suggestions. Martin Marietta also has an outstanding employee suggestion system, providing employees a method of presenting constructive ideas to management and, when implemented, providing recognition and awards. To date, the suggestion system has resulted in 2,120 implemented improvements and cumulative savings totaling almost $5 million. During the first nine months of 1986, the system received 1,787 suggestions, resulting in a participation rate of 45 suggestions per 100 employees. Of the suggestions received in 1986, 33 percent have been adopted, with a resulting first-year net savings of $663,631.

IBM has had a number of programs in place for several years which reward forward-looking employees. Two of them are the Suggestion Program and the Quality and Cost Effectiveness Program. From 1983 to 1985, the number of suggestions processed increased by 44 percent while estimated dollar savings increased more than 500 percent. Employee participation in the Quality and Cost Effectiveness Program increased 83 percent from 1983 to 1985, while estimated savings increased 700 percent. In addition, IBM has made a patent attorney available for consultations with employees on patent applications.

Once again, the key is leadership. Success stories such as these begin and end with leadership that recognizes the invaluable asset it has in its employees and their expertise — and encourages them to share their ideas.

Theme 5

Build Dedication, Pride, and Team Effort: Promoting Participative Management

There was a time not so long ago when one man could have a vision, assemble a team of workers, and produce a product that the world simply could not do without. Perhaps that phenomenon is still possible, but it happens less frequently than it did just a few years ago. Today, everything is more complex: one man cannot oversee the huge plants that are required to produce the products the world demands in mass quantities. One man cannot come up with the ideas required to continually improve his product, to expand his line, or to diversify into other areas to keep his vision alive. Satisfying the needs of an ever more demanding world market required teamwork, dedication, and a sense of pride in accomplishment on the part of employer and employees alike.

Martin Marietta has been particularly successful in establishing employee involvement as a fact of everyday employment through the implementation of their System Refinement Team (SRT) program. The SRT concept embodies a variety of employee structures, including work groups, task forces, and integrated and management teams. It is a flexible system that fits the design of the organization and involves management and employees in the improvement process. The SRT program at Martin Marietta Manned Space Systems has been so successful that in 1985 it was recognized by the International Association of Quality Circles as the best in the country.

Participative management is no newcomer to IBM either. Six years ago IBM Federal Systems Division began quality circles. After a period of time, the program evolved to the departmental level, with emphasis on tracking improvements based on quantitative measurements. Everyone in the work force is involved in a departmental quality improvement team, and special teams are often formed to study and make recommendations about a particular work activity. IBM FSD feels that its low rate of employee attrition (less than 2 percent) and high degree of pride and teamwork are a direct result of employees having a voice in how things are done.

Theme 6

Uncork Individual Talent: Controlling Bureaucracy

"If you're not part of the solution, you're part of the problem." That aphorism may be a little simplistic, but it does make a point. Sometimes the structure that was formed to make a corporation function smoothly grows to the point where it becomes an obstacle to efficient operation. We've all seen examples of this. Companies that cut through that cumbersome structure and encourage individuals to use their creativity are bound to be successful. Martin Marietta and IBM are excellent examples.

Martin Marietta encourages talented individuals to flourish. For example, in 1985 they introduced the Change Summary Amendment (CSA), management's documentation control procedure. The CSA allowed for processing of some changes that previously would have required a supplement document or a complete issue. The results were outstanding: 30 percent average reduction for supplements and 82 percent for issues. As at IBM, individual achievers are rewarded for their efforts in a number of ways: peer recognition, six-month sustained high achievement, "Silver Snoopy," Employee of the Month, Employee of the Year, the Director's Spot Award. In addition, the company gives supplemental incentive awards that specifically recognize individuals who exceed company performance goals and objectives.

Likewise, IBM's approach to uncorking the talents of its employees is through special recognition of their contributions and achievements, both individual and group. Individuals receive awards of $2,500 to $25,000, a framed certificate, and a desk set for outstanding quality improvement or sustained performance of quality. IBM also recognizes the efforts of quality improvement teams by inviting work teams to a coffee with the site general manager. Selection emphasizes teamwork in improving quality. There is no predetermined schedule for presenting awards or recognizing work groups; recognition follows completion of an outstanding achievement.

At Martin Marietta and IBM bureaucracy is not allowed to become a problem that stifles individual creativity; management there knows that solutions to problems come from the skill and knowledge of their employees and that by rewarding those employees for their efforts companies and individuals alike will flourish.

Theme 7

Modernize for Survival: Encouraging New Technology

Computers are the key that will unlock the future. Little is done nowadays that hasn't been touched in some way by computers. Food processing, automobile manufacturing, medicine, education: somewhere along the line a computer has solved a problem, kept track of a part, helped to diagnose an illness, kept track of profits and losses. And what's more, where computers are concerned it seems we've barely scratched the surface: faster, greater memory, smaller size, unimagined applications.

Martin Marietta has also employed computers to streamline their efforts. Their entire engineering data base is being converted to computer-aided three dimensional models. Eventually the entire system will be integrated, leading Martin Marietta Manned Space Systems to a near paperless factory. Their production-control data-reporting computer system provides personnel with a running status report on work in process and can provide rapid response information on variances. Martin Marietta has also worked with NASA to develop a variable pulse plasma arc welding process that has resulted in a 90 percent reduction in weld defects.

Also, not surprisingly, IBM has made outstanding strides in using computers to modernize, cut costs, and improve quality. One example among many involves the shuttle's onboard software development process. In 1983 it became apparent that reconfiguration of shuttle software systems needed to be more efficient. After an audit of procedures, skills were consolidated, the use of subcontractors was increased, and quality of the delivered product was improved, resulting in a reduction of time and effort to reconfigure the flight system. Errors were reduced to zero for the last six systems released.

Everything changes. Without change there is no progress. To be a part of that progress, American industry and business must keep up with technology, and must modernize its physical plants. Martin Marietta Manned Space Systems and IBM are leading the way; we can learn from them.

Theme 8

Maximize Human Capital: Developing Strategies to Improve Education and Training

An inevitable adjunct to the modernization of American business and industry is the need for on-the-job training and/or continuing education for employees. No longer is it sufficient for a worker to know only which button to push or which nut to put on which bolt. Tasks are more sophisticated, more complex. Much more is asked of today's employee, and so managers must become conditioned to consider training as part of the modernization process. Not only must the cost of new computers be budgeted for, the cost of training must also be taken into account. And that is not a negative. Allowing an employee to remain a button pusher or a nut turner for his entire working life is a terrible waste of a valuable resource. With education, people can do so much more. Both Martin Marietta and IBM know that to be the case.

At Martin Marietta nearly 82 percent of the total work force has attended developmental programs totaling more than 108,000 contract hours. These certification programs provide expertise in the areas of safety, skills/processes, tooling and facilities, and problem solving. Additionally, all employees are encouraged to upgrade their formal education through a policy of 100 percent reimbursement of tuition costs, books, fees, and other related course materials.

Similar programs exist at IBM, including their Tuition Refund Program and Graduate Work-Study Program. While not everyone takes advantage of these programs, all employees at IBM FSD are required to participate in continuing professional education programs as part of their job assignment. Requirements vary depending on position: managers must attend 40 hours of management training annually; technical professionals receive 40 hours annually of technical and professional development training; and administrative employees receive 20 hours of training annually based on company and employee needs. In addition, in 1983 quality awareness education was instituted for all employees. New managers at IBM are also given special training, including instruction in the quality improvement process.

Theme 9

Improve Quality/ Productivity Practices: Building a Quality Ethic

Theme 9 is really what this book is all about. Martin Marietta Manned Space Systems and IBM Federal Systems Division have earned the respect of customers and suppliers alike for their high productivity and the quality of their efforts. Certainly NASA, having selected them as recipients of this year's Excellence Award for Quality and Productivity, considers them deserving. They have amply demonstrated that quality and productivity are not simply buzz words with them, but they have become facts of daily life in the work place.

Martin Marietta's commitment to a formal productivity and quality improvement program began more than a decade ago and today encompasses all the functions that contribute to the engineering, manufacturing, delivery, and support of their NASA product. The story Martin Marietta tells in this book is well worth reading; the facts and figures of their report reflect the tremendous strides they have made in the quality of their products and the productivity of their employees.

IBM FSD's quality improvement program has shown results by systematically establishing measurements and goals for quality improvement in each work group, by examining and improving the work processes, by regular reviews of progress, by involvement of employees and subcontractors in the improvement process, and by continuing education and recognition of achievement. All of this resulted in a reduced error rate for shuttle flight software to near zero. Over a five-year period, IBM reduced to zero the errors in mission-unique data for the flight software; the last six flight software systems had no errors at all. A truly remarkable accomplishment.

Award Finalists' Recognition

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